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Wisconsin Inspection Bureau.

Over 4,600 Associate Members.

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International.

Pittsburgh fire fighters in action during blizzard on night of Dec. 30, 1929.

The Quarterly

Vol. 23 April, 1930 No. 4

The Thirty-fourth Annual Meeting. The thirty-fourth annual meeting of the Association will be held in Atlantic City May 12, 13, 14 and 15, but will find itself in new surroundings. The rebuilding of Haddon Hall has permitted an experiment in a meeting room long latent in the mind of the chairman of our executive committee, who is an officer of that beautiful hotel. Mr. Bell has desired to provide for the N.F.P.A. an auditorium of suitable dimensions, aloof from the confusion of first-floor activities, and with perfect acoustics. Such a room will be ready for us at our May meeting. The floor is pitched as in a theatre; the stage is low and intimate; the seats are comfortable and commodious, and the room is high above the streets and board-walk, insuring absolute quiet. It is a room in which discussion will be possible.

The natural resistance to the construction of such a room in a hotel, which Mr. Bell was able to overcome in the minds of his associates in the management of Haddon Hall, was economic and derived from the fact that it can be used only for meetings like our own. A pitched floor and fixed seats make this room unavailable for dancing, dinners, or any of the many hotel uses requiring a flat or level floor with seats that can be shifted. Hence it furnishes a sort of accommodation to us not duplicated in any hotel in the country. Instead of an assembly of chairs near a platform surrounded by acres of floor space echoing to the human voice, which has too often been our lot, we shall experiment in May with a meeting room that is the creation of a man long devoted to the N.F.P.A. and who had the N.F.P.A. in mind when it was designed.

* * * * *

The Declining Use of Lumber. The lumber production of the United States and Canada declined twenty per cent between 1909 and 1928, according to tables prepared from government reports, issued with the March 9 number of the *National Lumber Bulletin.* The same issue of the *Bulletin* contains an article on the remarkable decrease in fire losses in 1929 and previous years. Is there a relationship between the decreased lumber production and decreasing fire losses? There doubtless is a relationship, but it may not be so direct as would at first glance appear.

It is generally agreed that the increased use of fire-resistive materials in building construction is a large factor in the decreased fire losses. Experience shows, however, that the mere use of non-combustible materials in building construction gives of itself no assurance of fire safety; they must be properly employed to give the desired results. Experience also shows that lumber, properly employed in buildings, as in the heavy timber or so-called mill type construction, does not have an unfavorable fire record.

It has been the misuse of lumber as a material of building construction, rather than the mere fact of its use, that has been the contributing factor in the large fire losses of the past. And it may be reasonably argued that the decreases of the fire losses, in so far as building construction is a factor, are primarily due to the more intelligent use of all materials of construction, including lumber.

* * * * *

Fire Prevention in Government Buildings. The fire in the Executive Offices of the White House on Christmas Eve and the fire in the United States Capitol Building ten days later (both reported in the QUARTERLY for January) have focused public attention upon the necessity of safeguarding the numerous government buildings in Washington, many of which are old and of an inferior type of construction from the fire protection viewpoint, and which generally contain records, relics, paintings and other priceless and irreplaceable material, the loss of which would be nothing short of a calamity. Our older members will recall the efforts of our late member, Professor Ira H. Woolson, during the war period to have the Constitution of the United States kept where it would be safer from fire. After many discouragements Professor Woolson succeeded, but during the intervening years little has been done to improve the fire safety of our government buildings. The project for a National Archives Building has been languishing for a number of years with little or no progress visible to the casual observer.

In the matter of maintenance and housekeeping, an element of utmost importance in any fire prevention program, the protection of the government buildings, or at least the majority of them, seems to have been well organized. The Protection Division of Public Buildings and Public Parks of the District of Columbia has jurisdiction over the majority of the government buildings in Washington and maintains a competent inspection service and supervision over fire hazard features of the buildings under its jurisdiction. Captain R. C. Montgomery, chief of this Division, speaking before the Fire Waste Council of the United States Chamber of Commerce at its March meeting, reported that there have been 347 fires in government buildings under its jurisdiction for the seven years from 1923 to 1929 inclusive. So efficiently were these fires handled that the average loss per fire was only $3.70. This is noteworthy evidence of the value of the competent inspection and watch service.

Included in the buildings under the jurisdiction of this department are the temporary wooden structures erected during the war as office buildings which were intended soon to be demolished, but which have been continued in use pending the construction of permanent buildings. These structures of highly combustible construction would presumably have been destroyed by fire long before this were it not for the strict enforcement of "no smoking" rules, meticulous attention to housekeeping, and careful supervision of the entire structure.

In addition to the inspection service of the protection division of public buildings and public parks, some unified program for the fire safety of all government buildings in Washington is obviously needed, some program which would furnish fire protection engineering advice in the design of buildings, the protection of special hazards, etc. There are in the government departments a number of N.F.P.A. members who have been serving on our committees and are fully competent to give this service. It is gratifying to note that an interdepartmental conference on fire safety has recently been held which has as its purpose the development of a program of this character.

* * * * *

The Service of Licorice. The development of fire extinguishing methods has brought licorice into use as an ingredient in the powders producing foam blankets for smothering oil and other fires. Such use is mentioned in a recent report to the American Chemical Society, in which the helpful service of licorice root to industry is indicated.

"The licorice root is a contributor to human activities in no small degree," the researchers point out. "The primary extract serves the tobacco, pharmaceutical and confectionery industries; the secondary extract is a fire-extinguishing agent; and the residual fiber is a valuable raw material for cardboard boxes and provides a new structural material for the architect and builder."

A recent large-scale experiment in licorice culture in New Jersey, covering a period of several years, proved commercially unsuccessful, the researchers say.

The plant is now cultivated to a slight extent in Spain and Italy, but most of the licorice in those countries, as well as in Southern Russia, Asia Minor and Southern Asia, grows wild over wide areas, establishing itself so tenaciously that it can hardly be eradicated. It grows best in the fertile soil of the river valleys, and the perennial shrub reaches a height of two or three feet.

The roots are tough and fibrous; they may be an inch or more in diameter at the thickest portion and 25 feet in length. During the autumn months peasants dig these roots with primitive tools, such as have been used by their forefathers for thousands of years, and haul it to the nearest collecting station.

Near Symrna a small amount of green root is extracted for the European trade. Most of the roots, however, are piled in huge stacks for curing, where

they are left through the following summer until they become dry enough for baling. These stacks are covered during the rainy season to prevent mildewing, and they are also frequently turned.

When dry the roots are pressed into bales weighing about 300 pounds and shipped to the United States. This industry is, therefore, of great benefit to those comparatively poor regions, employing as it does many thousands of natives.

Upon arrival at the wharves of the American factories the baled root, amounting to about 35,000 tons per annum, is stored in warehouses according to the district from which it has come. The various brands of licorice extract that have been developed to meet the requirements of different consumers are made by blending roots which have been gathered in different regions.

Meeting of the Executive Committee.

January 18, 1930.

The midwinter meeting of the Executive Committee was held in Atlantic City, January 18, 1930. The following members were present:

Albert T. Bell, Atlantic City, Chairman
Eugene Arms, Chicago
W. H. Blood, Jr., Boston
George W. Elliott, Philadelphia
C. H. Haupt, Elizabeth, N. J.
W. F. Hickey, New Haven
George F. Lewis, Toronto
W. E. Mallalieu, New York
S. D. McComb, New York
H. L. Miner, Wilmington, Del.
S. L. Nicholson, New York
C. W. Pierce, New York
J. S. Trump, Philadelphia
F. C. Jordan, Indianapolis, President
F. T. Moses, Providence, Vice-President
Sumner Rhoades, New York, Vice-President
R. P. Miller, New York, Past-President
Dana Pierce, Chicago, Past-President
Franklin H. Wentworth, Boston, Managing Director

Mr. A. R. Small, N.F.P.A. representative on American Standards Association, was present by invitation.

Business Transacted.

The program of the 34th annual meeting, Atlantic City, May 12-15, was discussed. A proposal for adoption of a registration fee was laid upon the table.

The Managing Director reported progress in the project of incorporating the Association.

Informative Executive Office memoranda on Membership Solicitation, Advertising in QUARTERLY, and Field Service activities were received and discussed.

The sub-committee appointed to consider the proposal to convert the QUARTERLY into a monthly journal recommended no action at present.

It was voted to refer to the Electrical Committee the question of retaining in future editions of the National Electrical Code, Articles 37 (Radio Equipment) and 60 (Signaling Systems) or the transfer of the essentials of

these articles to other parts of the Code, with the request that the Electrical Committee report its decision in due course to the Executive Committee.

In view of the discussion of various communications on the subject, it was voted, on motion of Member Nicholson, that the Executive Committee should be recorded as of the view that organizations having representatives in the Electrical Committee should be kept to the smallest practicable minimum and that the present make-up is judged in general to provide a satisfactory spread of representation and a balance, but that representatives of additional coöperating bodies could be named to the membership of the Committee upon receipt of notice of formal recommendation to that effect from the Electrical Advisory Committee of the American Standards Association, it having been shown that the viewpoint of this Executive Committee had been duly considered in any action looking to increased membership which the Electrical Advisory Committee might propose.

An informal report on the present status of the American Standards Association was made by Mr. Small, to whom a cordial vote of thanks was given for his service to the N.F.P.A. in A.S.A. matters.

The progress report of the Electrical Field Service engineer on the project for an Electrical Field Practice Manual was discussed without action.

Technical Committee Affairs.

A Committee on Spontaneous Heating and Ignition was created as recommended by the Conference on Spontaneous Heating and Ignition of agricultural and industrial products called by the N.F.P.A. in coöperation with the United States Departments of Agriculture and Commerce on November 14 and 15, 1929, following action on this subject taken at the last annual meeting. Dr. H. H. Brown was appointed chairman and the Executive Office was authorized to complete the personnel.

The Recommended Good Practice for Gasoline Tank Trucks was adopted at the last annual meeting (Proceedings 1929, page 433), subject to authorization to the Committee on Flammable Liquids to add a suitable paragraph on fire extinguishers. This was done, as follows:

> Section 2. Protective Features. Add new paragraph:—
> 28. Extinguisher Required.
> Each truck or trailer shall be provided with at least one hand extinguisher of a type suitable for extinguishing gasoline fires.

Executive Committee approval of the above was voted.

The text on First Aid Fire Appliances recommended by the Committee on Field Practice following final review at its meeting January 15, 1930, was approved.

On recommendation from the Committee on Automatic Sprinklers, rule 421, Regulations on Automatic Sprinkler Equipments, was revised by the deletion of "one hundred and fifty pounds" and the substitution therefor of "one hundred and seventy-five pounds." (See Proceedings 1929, page 353.)

The following revisions of and additions to the personnel of various committees were confirmed:—

Aviation.

W. J. Austin, Aeronautical Chamber of Commerce.
H. Barber, Aeronautical Chamber of Commerce.
Halsey Dunwoody, Aeronautical Chamber of Commerce.
**Henry W. Foote (Philadelphia), Aeronautical Chamber of Commerce.
Charles S. Jones, Aeronautical Chamber of Commerce.
W. L. LePage, Aeronautical Chamber of Commerce.
Stephen McClellan, Aeronautical Chamber of Commerce.

Construction Operations.

*W. J. Barney, American Society of Civil Engineers.
*Avery Brundage, the Associated General Contractors of America, Inc.
*Frank R. Daniel, Wisconsin Inspection Bureau.
*C. G. Durfee, Fire Equipment Institute.
Joseph L. Hernon, National Association of Building Owners and Managers.
*John H. Kenney, Association of Fire Underwriters of Baltimore City.
*R. C. Loughead, Michigan Inspection Bureau.
*J. W. Moffett, American Society of Civil Engineers.

Dust Explosion Hazards.

J. A. Mull (replacing G. F. Ewe), Terminal Elevator Grain Merchants Association.
Schuyler Van Loan (replacing Walter D. Archibald), American Spice Trade Association.

Electric Power Houses.

C. W. Johnson, Conference Special Risk Underwriters.

Farm Fire Protection.

M. O. Cook (replacing Charles H. Meigs), Fire Equipment Institute.
Stanley Knisely, National Association of Flat Rolled Steel Manufacturers.
E. G. Lantz (replacing T. F. Laist), American Society of Agricultural Engineers.
Joseph P. Quinlan (replacing R. G. Kimbell), National Lumber Manufacturers Assn.

Fire Prevention and Clean-up Campaign.

Frank L. Brigham (Andover, Mass.).
J. H. Edwards (Seattle).

Fire Pumps.

P. E. Griffin (replacing E. E. Clark, deceased), Associated Factory Mutual Fire Insurance Companies.

Fire Record.

W. F. Farley (replacing F. W. Bucknam), Associated Factory Mutual Fire Insurance Companies.

Flammable Liquids.

R. C. Powell (replacing A. B. Cox), American Petroleum Institute.

Garages.

E. B. Langenberg (replacing A. M. Daniels), National Warm Air Heating and Ventilating Association.

Gases.

A. R. Stevenson, Jr., National Electrical Manufacturers' Association.

Private Fire Supplies from Public Mains.

Henry E. Halpin (replacing H. A. Burnham), Chairman, Associated Factory Mutual Fire Insurance Companies.

Protection Against Lightning.

D. V. Stroop, American Petroleum Institute.

Protection of Records.

R. P. Dryer, National Association of Safe Manufacturers.

Safety to Life.

J. M. Tracy, N.F.P.A. at large.

Richard E. Vernor, Western Actuarial Bureau.

Storage of Combustible Fibres.

Hugh Hill, Jr. (replacing S. E. Myrick), South-Eastern Underwriters' Association.

Thermostats.

*John H. Derby, Association of the Fire Alarm Industry.

*Henry A. Fiske, National Automatic Sprinkler Association.

Clarence Goldsmith, representing Committee on Automatic Sprinklers.

*John R. Hamilton, National Automatic Sprinkler Association.

*B. R. Martin, representing Committee on Automatic Sprinklers.

John C. Stevens, Association of the Fire Alarm Industry.

Visual Education.

S. L. Legreid, Fire Marshals Section.

W. A. Noel, U. S. Department of Agriculture.

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*Added to committee in accordance with authorization to Executive Office to complete personnel of new committee.

**Recommended as individual, rather than as representative of sprinkler industry.

Growth in City Planning.

A survey recently completed by the U. S. Bureau of Standards shows a growing interest in city planning in all parts of the United States. A tabulation made from returns to questionnaires sent to various cities, towns, and villages shows that at least 691 of these municipalities have official planning boards or commissions in existence. Of this number, 208 are cities having a population of over 25,000. The other 483 vary in size down to villages of less than 1000, and several of the smallest of these have less than 500 inhabitants.

Cities having planning commissions are believed to be more apt than others to exercise foresight and true economy in controlling the laying out and improvement of streets, the location of transportation facilities, in making provision for street traffic, and in the regulation of private use of land through zoning ordinances.

The tabulation, in addition to summarizing the total number of planning commissions now in existence, groups them according to States, and presents data as to the number of members composing each commission, the number of appointed members, and the number of ex-officio members, the terms of office and the title of the executive officer, and indicates which cities have zoning ordinances in effect.

—Technical News Bulletin, U. S. Bureau of Standards.

History of Building and Fire Prevention Codes.

By Frank Burton,
(Member N.F.P.A.).

Ordinarily we think of building codes as a strictly modern development, but a brief study of records of the past will show that this is far from the truth. Histories usually deal with wars, kings and other spectacular events and personages, while the humble builder does his work unnoticed. Such buildings of antiquity as attract universal attention are generally temples, castles or forts, which, from their very nature, are not affected by building ordinances, while the houses of the poorer peoples are largely ignored.

It is quite clear from such scraps of information as are still preserved, that in all ages and in all countries where important cities were built, the local governing authorities interfered in some degree with the building trades in the interests of public safety and well being. Because of the relatively limited number of persons interested in such matters, these laws, when in foreign languages, have seldom been translated. In many cases the records have been destroyed and this applies to many modern American cities when the older municipal acts are often no longer in existence.

In a general way one might say that in the beginning, building regulations were the outgrowth of civil rights, which for the better protection of the public were later issued as local regulations. The earliest regulations were intended chiefly to prevent the collapsing of buildings, which was remarkably frequent in antiquity. Later the resistance of structures to the spread of fire became the object of numerous restrictions, and lastly questions of sanitation were considered. It is only in our own time that there has been any serious attempt to regulate the details of engineering design, but this was due, no doubt, to the ignorance of design which made regulation of this sort difficult to formulate and almost impossible to enforce.

The earliest trace of building regulations which I have been able to find appears to be the royal marks upon the dry mud bricks used in the buildings of Ur, an ancient city of Asia Minor, from which the civilization of Egypt was obtained. Many explanations have been offered as to the reason for these marks, but the interpretation I put upon them was that the king held a monopoly of the manufacture and marked his product for identification. The monopoly was, no doubt profitable, but was maintained under the guise of a public necessity to protect building owners from poor materials.

This article is based upon a paper presented at the Fifteenth Annual Meeting of the Building Officials Conference, with matter on fire fighting and fire prevention added by the author.

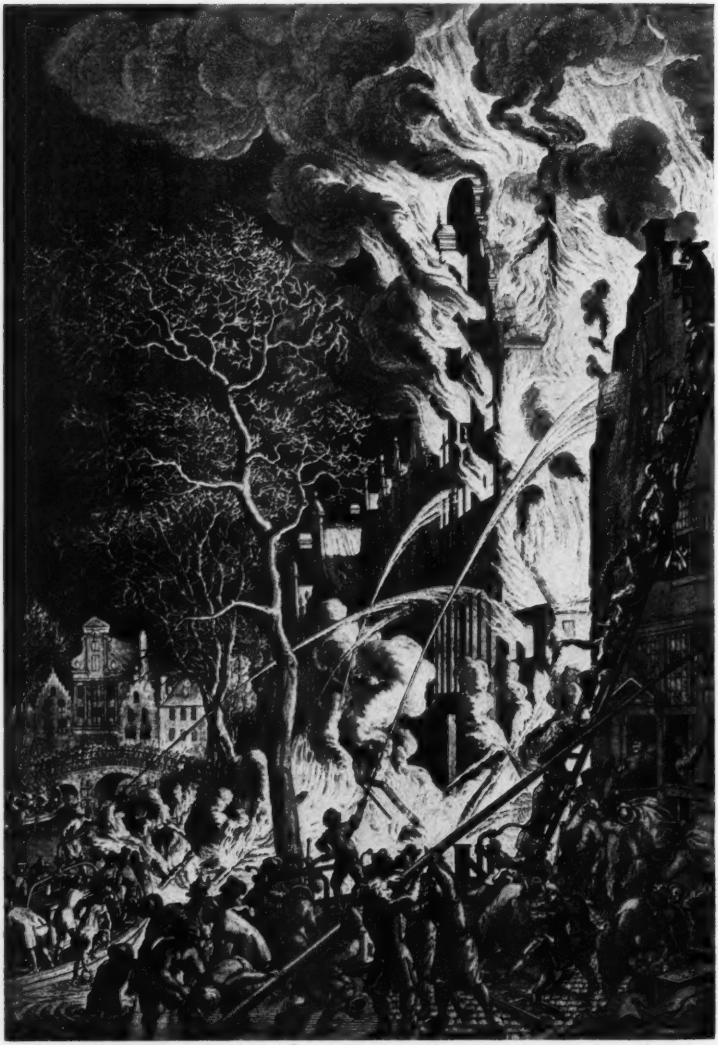
The first written regulations regarding building construction appear in the Code of Hammurabi, a king and famous law giver, who ruled Babylon about 2250 B.C. Several sections (Nos. 228 to 233) deal with the obligations of contractors to owners, and provide that if a house collapses and kills the owner the contractor shall be put to death. The maximum price per square foot of building was also established, as well as the wage scale for mechanics. The cost of a one-story house, 24 feet by 32 feet, was equal to 426 times the daily wage of a carpenter. At $5 a day this would equal $2,130.00, or not much less than the cost of a modern house without a basement.

Vitruvius, an architect who lived in Rome at the time of Augustus Cæsar (about the year one), relates that at "Utica (a city in Africa) in constructing walls they used brick only if it is dry and made five years previously, and approved as such by the authority of a magistrate."

Vitruvius notes that a Greek engineer, Cteribus, living some time before the year one, invented a machine for raising water to a great height. He describes the machine at length, and from a study of his description we can recognize a two-cylinder, single acting force pump with cylinders turned out of a bronze block, provided with wool gaskets, check valves and a lever for manual operation. It does not appear that this machine was ever actually used in antiquity.

As to Egypt and Greece, there seems to be little or no information preserved aside from the chance remark quoted from Vitruvius; but in Rome, the law giver of Europe, there is considerable information in existence, but only a very little has been translated into English. In the Roman Republic a number of "urban servitudes" were recognized, such as the right to rest beams on an adjoining neighbor's wall, the right to receive water from his eaves, or the right to force him to provide rain-water drains to dispose of the water; also the right to light from over his garden, and the right to limit the height or extent of his buildings were recognized as servitudes or easements belonging to the adjacent property. Such servitudes could be created by mutual agreement or by ancient usage, and, once established, could only be dissolved by mutual agreement. As the city grew larger numerous disputes arose, and it was often impossible to determine the rights of the various parties. Under the Empire, local regulations gradually replaced the servitudes, and the inspection of buildings was placed in the hands of the aediles, who were minor officers of considerable dignity, being custodians of the temples and having charge of the public games and the maintenance of pavements.

The Lex Julia Municipalis governed many aspects of building construction, but unfortunately the portions devoted to this subject are no longer in existence. The regulations regarding maintenance of pavements are, however, remarkably clear and well written.



New York Underwriters' Insurance Company.

An old Dutch print showing a fire occurring on December 29, 1669. Engraved in Amsterdam in 1690.

The originals of this and other old prints reproduced in this article were loaned for reproduction from the collection of Simon Brentano of New York.

Vitruvius mentions that an architect should have a fair knowledge of laws so that "he should know those which are necessary in the case of buildings having party walls, with regard to water dripping from eaves, and also laws about drains, windows, and water supply." Apparently mud-dried bricks were largely used at this time and gave considerable trouble, because there were numerous regulations intended to discourage their use, one of them being that no wall adjacent to a street could be more than 18 inches thick. Vitruvius defends the use of such bricks when properly made, but notes that an 18-inch wall will support only one story.

The reigns of Julius and Augustus Cæsar were days of rapid growth in Rome. Speculative builders erected apartment houses of great height, and many of them were poorly built, according to Vitruvius. Collapses appear to have been numerous, and Augustus enacted a law limiting the height to 70 feet. Later, under Trajan, this was reduced to 60 feet, because of the large number of collapses. Timber-framed walls filled with mud were common at this time, and small wooden buildings, although prohibited by law, were not uncommon. Under Nero a great many such buildings devoted to the sale of the Roman equivalent of "hot dogs" were constructed about the Circus Maximus, and it was a fire within one of these buildings which destroyed Rome and not an intentional act of Nero's. After the fire a serious effort was made to require the construction of masonry buildings, but no ordinances on this subject appear to have ever been translated.

Crassus' Fire Department.

There is a story that Crassus, an associate of Julius Cæsar, maintained a private fire department and attended all large fires in Rome. He would offer a small sum for the burning building, and if successful in purchasing it would extinguish the fire. If not, he would permit the fire to burn, meanwhile reducing his offer. He was reputed to have become the wealthiest man in Rome.

The people of ancient and medieval times had no way of raising large quantities of water to a sufficient height to fight fires, even when a large quantity of water was available, which was not usually the case. Also they had no fire-resistive material available for floor construction. The only effective fire prevention methods available were to build masonry walled buildings with incombustible roof coverings and when a large fire did occur in any building to abandon it. As a consequence building laws were enacted in most large European cities during medieval times requiring such construction, but the Scandinavian countries and England seem to have been rather backward in this respect. The City of London was burned repeatedly, yet no effective steps were taken to improve conditions until 1667.

The sanitary regulations of Rome were more complete and more thoroughly enforced than the building regulations, and without these it is quite certain that it would have been impossible to house so large a population in so limited an area. In the later days of the Empire, civil authority fell into

New York Underwriters' Insurance Company.

Fighting a fire in the Municipal Building in Amsterdam in 1652.

decay, and both sanitary and building regulations were openly ignored. Various evils followed, including pestilences, which drove the leading citizens to the north of Italy and left the city to the mercy of the barbarians.

From very early days each city of Europe exercised some form of restrictions on buildings and the various European countries have developed numerous complex systems of control. In Austria the greatest liberty is permitted the architect, but he is held criminally responsible for the results of his work. In Germany and France the restrictions are numerous and detailed, but engineering requirements as to stresses are very liberal compared with ours.

In London we find the most complete available example of building code evolution. In 1189 the first Lord Mayor, Henry Fitz-Aylwin, issued what was called the Assize of Building. It was a short document which empowered citizens to appear before the court of the Lord Mayor and Aldermen and demand protection from those encroaching on their rights. It provided for stone party walls at least 3 feet thick and at least 16 feet high on property lines, and provided for the procedure in building such walls in certain cases. The distances of cesspools from walls were established, rain-water gutters required, and it was stated that in case of a violation the work should be stopped until viewed by the Lord Mayor.

Apparently the Lord Mayor was to enforce the law and if he had done so all might have gone well, but it does not seem that he gave the matter

much attention. Actual building inspection was left to the scavengers (or street cleaners). I will quote the oath in the original spelling:

Scavenger's Oath.

"Ye shal swear that ye shal wel and diligently observe that the Pavements in every ward be wel and rightfully repaired; and not haunted by the Noyance of the Neighbours; and that the ways, Streets, and Lanes be kept clene from Donge and other filth, for the Honesty of the City. And that all the Chimnies, Reredoses, and Furnaces be made of stone, for defence of Fire; and if ye know of any such ye shal show it to the Alderman; that he may make due Redress therefor. And this ye shal not leve. So help you God and by this Book."

In 1212 an ordinance forbade thatch on roofs and required tile roofing. During this period, and for many years after, London suffered severely from fires, but still the ordinances do not seem to have been observed. In 1302 the Aldermen ordered the thatch torn off a roof, and for a time this ordinance appears to have been obeyed.

Little or no supervision was maintained as to signs, store show windows and similar obstructions, until the streets became so cluttered with these obstructions that they became almost impassable. Various ordinances were then passed establishing the maximum projection for store fronts and minimum height for signs.

One of the reasons for the numerous fires in London is evident from an ordinance in the time of Edward II (about 1330) requiring chimneys to be of stone, tile or plaster—timber chimneys (probably plastered with clay) being forbidden.

Some time toward the end of the sixteenth century a body known as the Commissioners of Buildings was established, but these officers appear to have been more honorary than active. The oath of the scavengers appears almost the same at this time as it did earlier, and we find that the Commissioners of Buildings sought the aid of the constables in discovering violations of the building laws, but we all know what the results were.

In Stow's Survey of London, published in 1633, we find the ordinances in force at that time. It is rather surprising that no mention is made of masonry party walls, although tiled roofs were required and shop fronts were not to be over $2\frac{1}{2}$ feet wide, and "jetties" not less than 9 feet high.

There seems to have been little or no progress in building legislation during four centuries, and in some respects the tendency has been backward. London at this time was undergoing a great change. Hitherto, England had relied upon imports of luxury articles from Spain and Italy, most of which were obtained in Constantinople, Egypt and Persia, but the incursions of Tartars and Turks into these countries and later into southeastern Europe destroyed this commerce. America had been discovered not long before and

New York Underwriters' Insurance Company.

Dutch villagers extinguishing a fire in 1673.

further explorations led to the establishment of colonies and extensive foreign commerce. London grew rapidly from a provincial town to a great city. Great numbers of foreigners, especially Frenchmen, settled in London, as well as huge numbers of people from the towns and rural districts of England. The housing conditions became very acute, particularly so because the lack of adequate transportation made it necessary for the workers to live close to their work. The situation had become so acute by 1580 that Queen Elizabeth issued a proclamation in the following words:

Queen's Proclamation of 1580.

"To the preservation of her People in Health, which may seem impossible to continue, though presently, by God's Goodness, the same is perceived to be in better Estate universally than hath beene in Man's Memorie; yet where there are such great Multitudes of People brought to inhabite in small Roomes, whereof a great Part are seene very poore, yea, such as must live of begging, or by worse Means, and they heaped up together, and in a sort smothered with many families of Children and Servants in one House or small Tenement; it must needes followe, if any Plague or popular Sickness should, by God's Permission, enter amongst those Multitudes, that the same would not only spread itself and invade the whole Citie and Confines but that a great Mortalitie would ensue the same, where her Majesties personal Presence is many times required.

"For Remedie whereof, as Time may now serve, until by some further good Order be had in Parliament or otherwise, the same may be remedied;

her Majestie, by good and deliberate advice of her Counsell, and being also thereto moved by the considerate opinions of the Lord Mayor, Aldermen, and other the grave wise men in and about the Citie, doth charge and straightly command all manner of Persons, of what Qualities soever they be, to desist and forbeare from any new Buildings of any House or Tenement within three miles from any of the Gates of the sayde Citie of London, to serve for Habitation or Lodging for any Person, where no former House hath bene knowen to have bene in the Memorie of such as are now living; and also to forbeare from letting or setting, or suffering any more Families than one onely to be placed, or to inhabite from henceforth in any one House that heretofore hath bene inhabited."

This document is probably about as bad an example of building legislation as we can expect to find. The results were exactly the opposite intended. The erection of new buildings was to a considerable degree checked, but the dividing of old buildings into small unsanitary tenements went merrily on.

For nearly a century the city authorities endeavored to enforce this law, being often prodded by royal authority, but all to no purpose. The conditions continued to grow worse, and in the fall of 1664 the plague came. For two years it continued unabated, practically paralyzing the business life of the city, and on September 2, 1666, a fire broke out which checked the plague but left London a smouldering ruin.

In the "Remembrancia of the City of London 1576-1664," which is a sort of City Clerks' journal, we find the following note relative to some correspondence:

"VIII. 202. Letter from the Lords of the Council to the Lord Mayor and Court of Aldermen, with respect to the late fire near Arundel House, at which the good use of the engines for spouting water manifestly appeared, though there were none brought until it was late, because there were no engines in the parishes near thereabout; recommending that a frequent provision should be made of them, so that they might be near and ready at hand on all occasions; and that the great parishes should provide themselves with engines, and the lesser ones should join together in providing them; and conveying their thanks to Mr. Sheriff Atkins, who did good service in person at the fire. 10th March, 1637."

The editor adds a very interesting note at the bottom of the page explaining the reference to engines for spouting water as follows:

"These were probably large hand-syringes: no reference to any engines, properly so called, appears for some years afterwards. About the year 1657, Hautsch invented a machine at Nuremberg, which was capable of raising a stream of water, an inch in diameter, to a height of nearly eighty feet. Vanderheide invented, in 1672, flexible hose. By an Act of Common Council, passed November 15th, 1667, it was enacted that the City should be divided

New York Underwriters' Insurance Company.

A contemporary print exhibiting the use of hose to extinguish fire in 1672.

into four quarters, and that each quarter should have 800 leathern buckets, fifty ladders, and two hand squirts of brass for each parish; and that each ward should provide a bellman to walk through its precincts from ten at night till five in the morning, to give an alarm in case of fire."

London's First Water Company.

In 1580 Parliament granted Peter Morice (a Dutchman) a charter for 500 years to pump water from the Thames and distribute it in London. This appears to have been London's first water company and it operated until 1822, when Parliament canceled the grant and paid the heirs of Morice £10,000 in damages.

In 1605 Parliament authorized the City of London to bring water from Amwell. The work was executed by Sir Hugh Middleton and was completed in 1613, but the undertaking was not a financial success. Later a Royal order required all citizens needing water to obtain it from this source. There appear to have been several other water companies operating within the next fifty years and numerous ordinances were enacted relative to taking water from mains without permission. These water mains were wooden logs with the center bored out. The hole in the butt end was flared and the other end of the log was tapered to fit into the flared opening. Leakage was excessive and pressure was not maintained all day, but was supplied for an hour or two morning and night. Householders filled vessels at these times to supply their daily needs. In case of fire a runner was sent to the pumping station to notify the company to supply pressure.

Church Wardens as Firemen.

By an act of Parliament in 1707 (6 Ann C 31) each church warden was required to have casks of water, one large engine and one hand-engine (probably large brass squirt guns). Also he was to provide a water pipe from the water main to the surface of the ground and have same plugged with a two-inch plug. Such pipes were to be provided at frequent intervals and a mark was to be placed on the adjoining building to indicate the location of the pipe in case it became covered up. Previous to this time it had been customary to dig down and tap a water main after the fire started. The act naïvely explains that this resulted in great loss of time.

An act of 1772 (Geo. III. 14, C 78) provided further for the payment of 10 shillings to any water company who furnished water to a fire and 30 shillings to the first fire company and 20 shillings to the second company arriving at a fire.

Entrusting fire fighting to the church wardens naturally did not lead to efficient fire protection. The fire insurance business had become large and powerful by this time and the insurance companies found it profitable to maintain private fire companies to protect the property they insured. Each company placed a brass plate on the front of each building insured and all answered each fire. When it was determined which company had insured the building the others usually retired unless the fire appeared to be threatening some adjacent property in which they were interested. At times arrangements were made for mutual assistance between the various companies, but generally there was a spirit of rivalry and jealousy. The growth of the private fire companies permitted the public fire-fighting forces of London to fall into disuse and finally to disappear.

In 1832 the various insurance companies united their fire departments in one company known as the London Fire Engine Establishment, with 80 men, 19 stations and costing at the start 8000 pounds annually. In 1834 the House of Parliament took fire. The Fire Engine Establishment declined to attempt to check the fire because the building was not insured and there appears to be no record of the appearance of any parish companies. Following the fire, public opinion demanded a community-owned fire department, but nothing was done until 1865 when the Metropolitan Fire Brigade act was passed whereby the County of London took over the Fire Engine Establishment and made it the nucleus of a public department.

In America the insurance companies never became so powerful in the early day, but volunteer fire departments, which were half social, half political clubs, became popular at an early date and after passing through many vicissitudes were converted into paid municipal companies. In the case of our larger and older cities this change was effected between about 1865 and 1872.

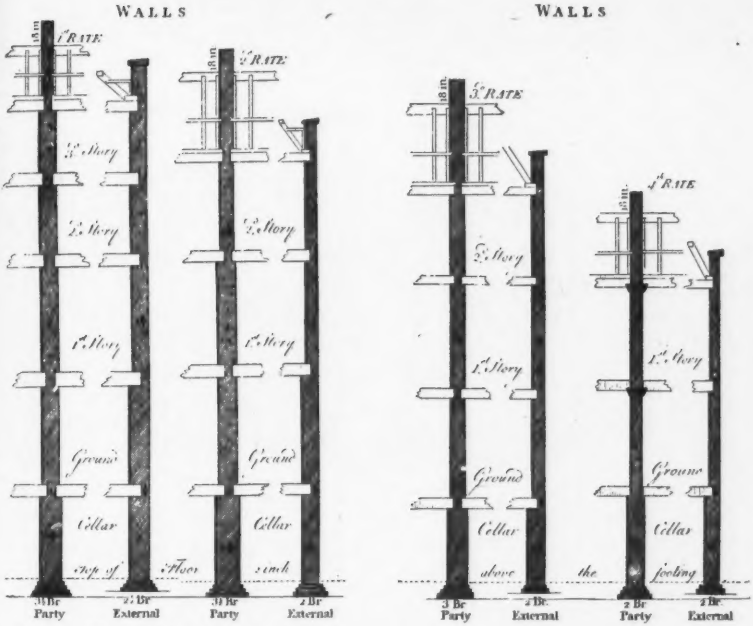
New York Underwriters' Insurance Company.

A contemporary print of the great fire in London—1666.

Modern Building Legislation Follows London Fire.

It was from the ruins of the London fire of 1666 that building legislation as we know it today arose. Parliament was promptly called in special session, and early in 1667 (Car. II-19-C3) passed an act, entitled "An Act for Rebuilding the City of London." This is quite an extensive document, providing a jail sentence for violation. It does not mention any type of building excepting dwellings, probably because all stores and workshops were within dwellings, and theaters, which were quite popular, were not permitted within the city limits. Dwellings were divided into four classes, depending upon the width of streets upon which they faced. Minimum ceiling heights of from 8 to 9 feet were required and buildings were limited to 2 to 4 stories with cellar and attic. Masonry walls were required for all exterior and party walls. Wall thicknesses were 8 inches for attic story, 12 inches for next two stories, and 16 inches or 20 inches below. Exterior balconies had to be of iron, rain-water leaders and gutters were required, and store-front posts were to be of oak. The act contains a vast amount of detail and closes with a list of required timber sizes for different spans and a number of provisions relative to construction of chimneys, spacing of joists, bearing of girders and similar matters. According to our present stresses, the minimum girder sizes would carry a 50-pound live load, but the minimum joist sizes would carry 167 pounds per square foot.

The act also provided for the widening of all streets less than 14 feet wide. Among the survivors of the fire was Sir Christopher Wren, then a young man, but probably the most brilliant builder England ever produced. He



Insurance Library, Boston.

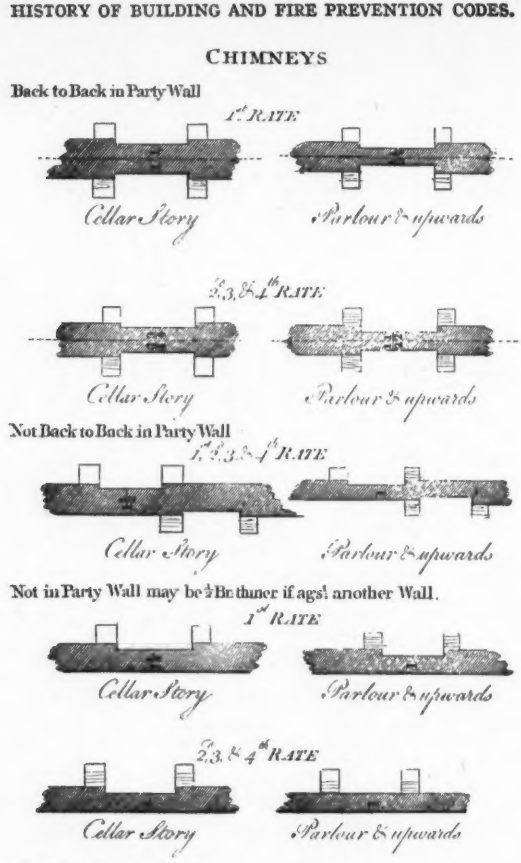
Illustration of requirements for walls, from "An Act for Regulating of Buildings and Party Walls and Preventing Mischiefs by Fire in London and Westminster. Passed in 14th Year of George III." Printed by I. and J. Taylor in 1796. (See also illustration on next page.)

appeared before the civil authorities and urged that the city be rebuilt with wide streets, parks and open places. His advice was disregarded, and London was rebuilt upon the old lot lines, with narrow, winding streets and lanes. How unfortunate it was that his plan was not followed.

In the Act of 1667, surveyors were appointed to enforce the act, and these appear to be the first active officials who devoted their energies to this work in England.

In 1670 (Car. II-22-C-11) some amendments were made to this act, one of them requiring builders to take out a permit from the city chamberlain at a cost of 6s. 8d., which included the laying out of the foundation by the surveyor.

In 1772 (Geo. III-12-C-73) further changes were made, bay windows were prohibited, a fine of £50 provided for improperly built chimneys, and property owners were empowered to tear down timber party walls, proving that the act had not been obeyed in all cases. Also certain dangerous occupancies, such as the distillation of turpentine, were regulated, but the requirements as to timber sizes were omitted, and no provisions as to engineer-



Insurance Library, Boston.

Requirements for Chimneys from London Building Code of 1796. (See also illustration on preceding page.)

ing details of interior construction appear in any English building act after this time.

In 1774 (Geo. III-14-C-78) the act was considerably modified and a very complex classification of building introduced, which I am unable to decipher. It was intended to govern factories and warehouses as well as dwellings, provide for wall thicknesses and other matters, and contained a large amount of detail on party walls.

In 1844 an important change was made in the system of building inspection. An act known as the Metropolitan Building Act (7 & 8 Victoria C-84) was passed which established a uniform code and system of inspection over the cities of London and Westminster and some 27 parishes, forming what we now call London, or, more properly, the County of London.

The Commissioner of Works and Buildings was to be the final authority, assisted by a Board of Official Referees and the district surveyors. The Board of Official Referees supervised the erection of public buildings and warehouses and acted as Board of Appeals. The penalty for failing to take out a permit was to pay three times the permit fee. Architects were required to call special inspections after completing framing of buildings. Extensive details of procedure regarding party walls were given as well as procedure in the case of dangerous buildings.

Numerous regulations as to dangerous and unsanitary trades and occupations were set down and the details of executing work, keeping records, and similar matters are covered. It was provided that the Official Referees were not to receive over £1,000 a year. An interesting detail is the provision that after 1846 no basement could be rented as a tenement separately from the upper stories of a building.

In 1855 the Metropolitan Management Act was passed, which considerably modified the building act of 1844 and extended the powers of the Metropolitan district to cover many phases of city engineering. A county or superintending architect was appointed to take full charge of building inspection, and all authority was centralized in his hands. The Official Board of Referees, which had become very unpopular, was dropped, and the requirements of the code somewhat simplified. Further amendments were made in 1860, 61, 62, 69, 71, 78, 82, 90 and 94. The complex classifications of 1844 were omitted, requirements simplified but made more definite, and provisions as to housing, such as room sizes, courts, yards, ventilation introduced, until we find in the 1894 act a modern and workable code quite different from American codes, so far as engineering goes, since there are no stress requirements mentioned, but containing practically all of the housing provisions now found in our state housing codes, and being remarkably clear and practical in matters pertaining to construction of chimneys, walls, fire stops, and other essential details of construction. Since that time it has been supplemented by numerous local regulations.

Development of Building Codes in America.

The development of building codes in America is very complex because of the large number of legislative bodies who have contributed acts bearing on this subject. The great majority of these are municipal ordinances and the records are only available locally. I will confine myself to mentioning two or three state acts given in the rather incomplete records available to me.

In the colony of New York in 1703 an act established the legal size of brick at 9″ x 4¼″ x 2½″ and provided a fine for failure to conform to these dimensions. In 1773, this was amended to forfeit illegal sized bricks to the Hospital of New York. Some time previous to 1775, an act was passed, entitled "An Act for the Regulation of Buildings and the Prevention of Fires."

I have not been able to find this act, but it was probably a fire limits ordinance. In 1775, this act was amended because it had been frequently violated and a better method of enforcement was necessary. The amended act permitted the construction of frame buildings in certain districts and also upon filled land, but required the owner of such land to notify the sheriff to assemble a jury of 12 free-holders to determine whether or not the land would sustain the weight of a masonry building. The oddest provision was a requirement that each alderman must present to the justices of the Supreme Court at the opening of each term of court a list of the buildings erected in their wards since the last term. These lists were to be submitted to the grand jury for investigation. The act expired in 1777, when the colony adopted a new charter, and for some years after no building laws were passed by the state authorities and none appear in the compiled laws of 1807. No doubt there are some local acts, but the records are not available to me.

In early times the town of Boston suffered greatly from fires, and the building laws of early date seem to have been passed wholly with a view of preventing the spread of fire. The first act was in August of 1679, ordering that dwelling houses should be erected of stone or brick and covered with slate or tile, etc., and this seems to be the forerunner of the requirements for fire-resisting building construction. Between that time and 1871 about two score of acts were passed, but as no one was designated to enforce these laws they seem to have availed but little.

In 1868 a tenement house act for Boston was passed, providing for ventilation and sanitary requirements, prohibiting the renting of basement dwellings, requiring 8-foot ceilings and windows one-tenth the area of the room. In 1870 (C-375) an act permitted cities other than Boston to establish fire limits.

An act of 1871 (C-280) established in Boston a department for the survey and inspection of buildings, and permitted the local council to establish fire limits (called building limits). The act required builders to obtain permits and present plans of public buildings. Wall thicknesses were given, details of roof, chimney construction and related matters covered, and the tenement-house code of 1868 was somewhat modified and incorporated in this act. All previous acts were repealed. Procedure was provided in the case of dangerous buildings, but there are no references of floor loads or permissible stresses.

There were some slight amendments in 1872 (C-260) and in 1873 (C-298)—a new provision required buildings over 80 feet high to be fireproof. The effort to describe fireproof construction indicates a distinct lack of comprehension of essential principles. No fireproofing is required on steel or other metals. An amendment of 1877 (C-214) relates to the stair requirements and inspection of factories and two amendments in 1882 (C-208 and C-252)

require safety devices on elevators and empower Boston to authorize the construction of elevators, license plumbers, and establish the thickness of walls not of brick or stone.

In 1888 (C-426) an amendment relative to public buildings provides for exits, requires fire-resistive theater curtains, fire extinguishers, and numerous similar details. In 1891 buildings were limited to 125 feet in height.

In 1892 (C-419) an entirely new code was adopted, which, for the first time in this state, contained stress requirements. Permissible stresses on wood, steel, cast iron and masonry are given, there being a complete loading table for timber and cast-iron columns. For the completeness of engineering requirements in this code, it would appear that in some other city, probably New York, a similar code had been adopted previously, but I have no exact information on this point. In 1907 (C-550), another new code was adopted, which, with numerous amendments, is now in force.

Since about 1900 the number of building codes in America has become so great and the changes so numerous that it is meaningless to attempt to trace any one code. The general tendency has been to make codes more complete, more detailed, to embrace an ever-widening circle of new building materials and gradually to decrease floor-load requirements and increase stresses on materials. The divergence of opinions on the various details has been very great, however, and in 1921 the United States Department of Commerce, under Secretary Hoover, undertook to lead the way toward a standard of requirements for some of the more important points by issuing various pamphlets on certain phases of building code work. A committee, originally headed by the late Prof. Ira H. Woolson (member N.F.P.A.), took up this work. A number of pamphlets on various phases of building regulation have already been issued and others are in process.

U. S. Fire Losses for 1928 and 1929.

Compiled by National Board of Fire Underwriters.

The United States fire losses for 1928 were $464,607,102, according to the final figures of Actuarial Bureau of the National Board of Fire Underwriters published in the winter issue of *Safeguarding America Against Fire.* This figure supersedes the original estimate of the 1928 fire loss made by the National Board as published in the July, 1929, QUARTERLY, page 28.

American Fire Losses Compared, 1927-1928.

Causes	Recorded Loss 1927	1928
Matches—Smoking	$29,345,929	$27,902,919
Defective Chimneys and Flues	19,523,904	19,588,878
Stoves, Furnaces, Boilers and Their Pipes	17,986,432	19,311,169
Electricity	12,360,588	14,905,816
Sparks on Roofs	11,256,303	12,932,552
Petroleum and Its Products	12,691,718	12,207,297
Spontaneous Combustion	13,640,804	12,112,461
Lightning	9,084,630	7,708,530
Hot Ashes and Coals	5,171,491	4,953,769
Open Lights	3,578,701	4,909,768
Sparks from Combustion	4,121,148	4,401,368
Sparks from Machinery	5,812,466	3,478,454
Miscellaneous Known Causes	3,408,359	3,397,498
Rubbish and Litter	1,035,454	2,939,182
Gas, Natural and Artificial	3,100,828	2,561,934
Incendiarism	2,403,615	2,466,034
Ignition of Hot Grease, Tar, Wax, Asphalt, etc.	1,699,208	2,109,299
Explosions	4,725,857	1,147,631
Fireworks, Firecrackers, etc.	893,663	693,996
Steam and Hot Water Pipes	184,931	407,319
*Exposure (including Conflagrations)	45,082,747	41,219,494
Unknown Cause	171,038,429	170,330,314
Total	$378,347,175	$371,685,682
25% to Cover Unreported Losses	94,586,794	92,921,420
	$472,933,969	$464,607,102

1929 Losses.

Fire losses for 1929 are estimated by the National Board at $422,215,128. This estimate marks the inauguration of a monthly reporting service based upon the loss reports of the member companies of the National Board. Hereafter these figures are to be published by the New York *Journal of Commerce* in lieu of their estimates based upon fires involving a loss of $10,000 or over

*Losses due spreading fires originating from various causes.

with a percentage added to cover unreported fires. (See QUARTERLY, January, 1930, page 215.) The following are the monthly totals for 1929:

January	$44,713,825	August	$30,446,893
February	41,520,290	September	29,249,355
March	41,277,814	October	31,652,385
April	36,845,795	November	29,061,869
May	32,129,408	December	39,726,338
June	33,605,663		
July	31,985,493	Total	$422,215,128

Comparison of U. S. Fire Losses, 1927-1928, by States.

State	Recorded Loss 1927	1928	State	Recorded Loss 1927	1928
Alabama	$6,470,182	$5,018,250	New Hampshire	$1,997,797	$2,309,508
Arizona	900,536	5,153,964	New Jersey	17,450,048	14,429,161
Arkansas	4,710,283	1,250,067	New Mexico	585,295	797,243
California	20,000,272	19,191,422	New York	48,559,113	46,096,581
Colorado	2,117,429	2,128,957	North Carolina	6,569,743	6,848,123
Connecticut	5,755,693	4,577,505	North Dakota	1,914,089	1,532,200
Delaware	561,821	346,685	Ohio	16,273,928	19,807,916
Dist. Columbia	806,344	568,066	Oklahoma	6,438,201	5,916,802
Florida	7,602,780	5,750,643	Oregon	3,110,627	3,805,934
Georgia	6,662,001	6,127,650	Pennsylvania	26,632,697	25,007,634
Idaho	942,426	1,223,376	Rhode Island	2,167,723	2,511,645
Illinois	27,940,545	26,018,706	South Carolina	4,259,478	3,883,396
Indiana	8,920,949	9,162,604	South Dakota	1,473,522	1,428,841
Iowa	5,424,164	5,018,066	Tennessee	7,643,290	8,364,477
Kansas	3,898,337	5,814,344	Texas	17,401,085	18,087,207
Kentucky	6,518,358	6,196,713	Utah	1,338,746	1,029,962
Louisiana	6,933,711	7,666,351	Vermont	872,021	1,054,919
Maine	3,870,172	3,666,892	Virginia	5,145,424	5,617,637
Maryland	3,785,401	5,186,973	Washington	6,913,294	6,592,812
Massachusetts	19,887,677	20,376,808	West Virginia	5,484,186	4,283,366
Michigan	16,367,390	13,498,649	Wisconsin	7,052,535	7,609,312
Minnesota	7,180,063	7,054,107	Wyoming	450,609	434,028
Mississippi	5,332,890	5,135,013	United States	$378,347,175	$371,685,682
Missouri	11,143,069	12,287,782	25% for Unreported Losses	94,586,794	92,921,420
Montana	1,679,420	2,451,831	Total	$472,933,969	$464,607,102
Nebraska	2,920,494	3,078,234			
Nevada	281,317	287,320			

Annual Fire Losses in the United States from 1916 to 1929 Inclusive.

1916	$258,377,952	1923	$535,372,782
1917	289,535,050	1924	549,062,124
1918	353,878,876	1925	559,418,184
1919	320,540,399	1926	561,980,751
1920	447,886,677	1927	472,933,969
1921	495,406,012	1928	464,607,102
1922	506,541,001	1929	422,215,128

The Fire Waste Council's Casualty Statistics.

The Fire Waste Council of the Chamber of Commerce of the U. S. A. has recently completed a survey of fire casualty statistics based upon data collected from a number of typical states. This information summarized in the tables printed below was presented at the March, 1930, meeting of the Fire Waste Council by its Committee on Fire Casualty Statistics. These figures are a consolidation of the results of six surveys of three months each made in a number of typical states, the number of states included varying in the different survey periods, averaging about a dozen. The method of compilation of statistics was primarily from newspaper clippings, a subscription to newspaper clipping agencies in each state giving the information. The data secured in this way were supplemented to some extent by information from other sources.

In presenting this information the committee realizes its limitations, both in the matter of the limited territory covered and the difficulty of getting anything like complete information from newspaper clippings. There are a large number of deaths and injuries by fire which are not reported in the newspapers. This applies particularly to the cases where deaths follow from some indirect cause some time after the date of the fire.

While not regarded as sufficiently complete to form the basis of any estimate of the total number of casualties occurring in the United States, these figures are exceedingly valuable as a representative cross section of fire casualty experience, showing the location of the fatal fires, the distribution according to age and sex, the type of occupancy involved, and the classification of the cause of the casualty. It is interesting to note that approximately two-thirds of the deaths occurred in the city and one-third in rural districts, and that two-thirds of the deaths are classified as women and children. In the type of occupancy involved the dwelling house fire leads in both deaths and casualties. In the classification of causes of casualties the larger proportion are classified as burns, and a relatively small proportion of both deaths and injuries are classified as suffocation, exposure, panic, etc.

Owing to the aforementioned difficulty in securing information on casualties resulting indirectly from fires, particularly where death does not occur until some later date and is reported as due to pneumonia or some other disease not ordinarily thought of as the result of fire, it may be that the classification of casualties due to other than direct burns would be a larger percentage of the total if more complete figures were available.

The total annual loss of life by fire in the United States has been generally estimated as approximately 10,000. The ratio of deaths to injuries

shown in the following table is approximately one to two and one-half. If this ratio may be similarly applied to the estimated annual loss of life by fire, it would appear that the total number of injuries due to fire in the United States may be as high as 25,000 annually.

	Deaths.		Injuries.	
	Number	Per Cent	Number	Per Cent
I. Location				
City	1710	65.0	5138	80.1
Country	873	33.1	1205	18.8
Not stated	48	1.8	72	1.1
Total	2631	100.0	6415	100.0
II. Age and Sex				
Male adult	953	36.22	3697	57.6
Female adult	732	27.82	1544	24.0
Male, 10-16	79	3.0	237	3.7
Female, 10-16	78	3.0	126	2.0
Child under 10	782	29.72	725	11.3
Male, age not stated	6	.2	72	1.1
Female, age not stated	1	.04	14	.2
Total	2631	100.00	6415	100.0
III. Type of Occupancy Involved				
No building involved	224	8.51	818	12.8
Dwelling	1635	62.1	2738	42.7
Apartment, hotel, rooming house	102	3.9	358	5.6
School, church, etc.	10	.4	80	1.2
Theatre, lodge room, etc.	11	.4	74	1.1
Industrial	127	4.9	497	7.7
Mercantile	40	1.5	514	8.0
Office building	17	.6	80	1.2
Garage	21	.8	222	3.5
Barns and other farm buildings	27	1.02	93	1.4
Warehouse	3	.1	34	.5
Lumber yard	—	—	21	.3
Automobile	116	4.4	334	5.2
Boat	33	1.3	70	1.1
Railway car	19	.7	36	.6
Miscellaneous	69	2.6	216	3.4
Not stated	35	1.3	157	2.4
Hospital, jail, etc.	143	5.4	73	1.1
Total	2631	100.0	6415	100.0

The following table shows the causes of casualties. The classification is in accordance with the cause of the casualty rather than the originating cause of the fire. Thus a fire, due to a defective chimney, in which people were suffocated would be classified as "Suffocation."

	Causes.	Deaths. Number	Deaths. Per Cent	Injuries. Number	Injuries. Per Cent
I.	**Burns Causing Casualty**				
	1. *Burning Structures*				
	Finished buildings	510	19.4	512	8.0
	Building construction, tents, etc.	9	.3	21	.3
	Autos and other transportation carriers	106	4.0	132	2.1
	Total	625	23.7	665	10.4
	2. *Prairie or Forest Fires*	8	.3	17	.3
	3. *Explosions*				
	Explosives, firearms, etc	32	1.2	113	1.8
	Dust explosions	3	.1	13	.2
	Mine explosions	2	.1	16	.2
	Gas explosions	119	4.5	591	9.2
	Others	55	2.1	258	4.0
	Total	211	8.0	991	15.4
	4. *Flammable Liquids*				
	In lighting devices	47	1.8	115	1.8
	In heating devices	381	14.5	749	11.7
	In power devices	67	2.5	292	4.6
	In cleaning operations	49	1.9	253	3.9
	Others	107	4.1	370	5.8
	Total	651	24.7	1779	27.7
	5. *Open Flames*	558	21.2	703	11.0
	6. *Carelessness with Matches*	125	4.8	248	3.9
	7. *Careless Smokers*	60	2.3	188	2.9
	8. *Use of Electrical Equipment*	20	.8	93	1.4
	9. *Use of Fireworks*	14	.5	121	1.9
	10. *Celebrations*				
	Christmas	3	.1	13	.2
	Other holidays	1	.04	9	.1
	Others	1	.04	—	—
	Total	5	.2	22	.3
	11. *Miscellaneous*	75	2.9	157	2.4
	TOTAL BURNS	2352	89.4	4984	77.6
II.	**Suffocation or Inhalation of Smoke and Gases**	199	7.6	360	5.6
III.	**Exposure from Fire**	10	.4	180	2.8
IV.	**Panic, Jumping from Buildings, Collapse of Buildings, etc.**	22	.8	164	2.6
V.	**General Accidents**				
	1. In response to alarms, falling from ladders, etc.	20	.7	393	6.2
	2. Other accidents incident to fire	11	.4	275	4.3
	3. Traffic accidents due to false alarms	4	.2	28	.4
	Total—General Accidents	35	1.3	696	10.9
VI.	**Shock**	13	.5	31	.5
	GRAND TOTAL	2631	100.0	6415	100.0

The Explosive Limits of Petroleum Vapors.

By G. W. Jones and G. St. J. Perrott,*
U. S. Bureau of Mines.

A knowledge of the explosive limits (or limits of flammability) of hydrocarbon gases is of great importance to everyone associated with the production and utilization of petroleum and its products. This information is of especial importance to the safety engineer, who must strive to eliminate as far as possible all dangers of explosions in plants that are under his supervision.

Composition of Petroleum Vapors.

Petroleum is a complex mixture of many different combustible hydrocarbons of widely varying boiling points. It is obvious that combustible vapors are therefore always present, and prevention of explosions can only be accomplished by maintaining the combustible vapors in such proportions as to be non-explosive, even if ignition sources are present. This may be obtained by the proper control of the air present or by reducing the oxygen content of atmospheres in which explosive vapors are present to such a value that explosions are impossible.

The lighter combustible vapors from petroleum and its products consist largely of saturated hydrocarbons (see Table 2 for detail) and, as shown later, each individual hydrocarbon vapor has a different explosive limit. It therefore becomes necessary to know what hydrocarbon vapors may be present before the explosive limits can be predicted.

Several years ago a survey[1] was made to determine the composition of the hydrocarbon gases and vapors which may be liberated by petroleum and its products in storage tanks, tankers, and similar places. The results of these tests are given in Table 1 following:

The table also gives the average number of carbon atoms per molecule in the gas or vapor. This does not mean that the values given are the only gases or vapors present, but rather the average of those present. For example: the first sample in the table indicates four carbon atoms to the molecule, or that the gas is butane. This was the average composition given by analysis. Separation of the vapors in this sample into the individual constituents would likely have revealed the presence of ethane, propane, pentane, and perhaps other hydrocarbon vapors.

Inspection of the table shows that the predominating gases and vapors

*Published by permission of the Director, U. S. Bureau of Mines. Mr. Jones is Chemist and Mr. Perrott is Superintendent at the Pittsburgh Experiment Station, U. S. Bureau of Mines.

[1]Jones, G. W., and Yant, W. P., Detection of Small Quantities of Petroleum Vapors with the Burrell Methane Indicator. Bureau of Mines technical paper 352, 1924, 19 pp.

Table 1.—Percentage and average carbon content of petroleum vapors taken from different places about petroleum refineries.

Source and description	Average molecular carbon content of petroleum vapor*								Petroleum vapor, per cent	Remarks
	1	2	3	4	5	6	7	8 or more		
	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}	C_6H_{14}	C_7H_{16}	.....		
Heavy Mexican crude-oil storage tank	.....	.....	.....	4.0	.....	.....	.....	.....	3.5	Explosive.
Do	.....	.....	.....	4.2	.....	.....	.....	.....	3.4	Do.
Do	.....	.....	.....	4.3	.....	.....	.....	.....	1.8	Do.
Light Mexican crude-oil storage tanks:										
Sampled 6 feet above oil	.....	.....	.....	3.9	.....	.....	.....	.....	5.8	Do.
Receiving oil from tanker (sampled 10 feet above oil)	.....	.....	.....	4.0	.....	.....	.....	.....	5.2	Do.
			....	4.4	.....	.....	.....	.....	5.3	Do.
			....	4.3	.....	.....	.....	.....	5.3	Do.
Do	.....	.....	....	4.0	.....	.....	.....	.....	4.7	Do.
			3.4	.....	.....	.....	.....	.....	4.9	Do.
Sampled just above oil	.....	.....	.....	3.8	.....	.....	.....	.....	3.5	Do.
Sampled 15 feet above oil	.....	.....	.....	3.9	.....	.....	.....	.....	6.0	Do.
Sampled 5 feet above oil	.....	.....	.....	4.2	.....	.....	.....	.....	6.4	Do.
Sampled above oil	.....	.....	.....	3.7	.....	.....	.....	.....	4.0	Do.
Sampled 1 foot above oil	.....	.....	.....	4.0	.....	.....	.....	.....	2.8	Do.
Mid-Continent crude-oil storage tanks:										
Sampled 8 feet above oil	.....	.....	.....	3.8	.....	.....	.....	.....	3.7	Do.
Sampled 1 foot above oil	.....	.....	.....	4.0	.....	.....	.....	.....	5.2	Do.
Do	.....	.....	.....	3.6	.....	.....	.....	.....	5.8	Do.
Do	.....	.....	.....	3.7	.....	.....	.....	.....	4.1	Do.
Crude-naphtha distillate and finished-product tanks:										
Direct from skimming plant	.....	2.1	.....	.....	.....	.....	.....	.....	5.7	Do.
Direct from coke stills (sampled 1 foot above oil, probably cracked).	.....	2.1	.....	.....	.....	.....	.....	.....	26.90	Explosive when diluted with air.
Direct from coke stills	.....	2.5	.....	.....	.....	.....	.....	.....	1.3	Not explosive.
Pressure-still distillate	.....	.....	3.4	.....	.....	.....	.....	.....	10.3	Explosive when diluted with air.
Crude-naphtha storage	.....	.....	.....	3.7	.....	.....	.....	.....	30.4	Do.
				4.5	.....	.....	.....	.....	1.19	}
Crude heavy naphtha	.....	.....	.....	3.6	.....	.....	.....	.....	1.61	{ Not explosive.
Untreated gasoline:				4.1	.....	.....	.....	.....	21.8	Explosive when diluted with air.
Tank nearly full	.....	.....	.....	4.5	.....	.....	.....	.....	22.7	Do
Little oil in tank and lower manhole open (sampled 2 feet above oil).	.....	.....	.....	.....	5.2	.....	.....	.....	3.5	Explosive.
Little oil in tank and lower manhole open	.....	.....	.....	.....	.....	6.3	.....	.....	3.6	Do.
Finished naphtha:										
Taken from dome of tank car	.....	.....	.....	.....	.....	6.5	.....	.....	4.9	Do.
Do	.....	.....	.....	.....	.....	.....	6.8	.....	4.9	Do.

Refined gasoline:										
Low-grade gasoline (sampled 6 inches above oil)	.....	.....	.....	4.5	.....	.....	.....	.....	12.0	Explosive when diluted with air.
Low-grade gasoline; some oil (sampled 4 feet above oil)	.....	.....	.....	.....	5.3	.....	.....	.....	3.2	Explosive.
Low-grade gasoline; some oil (sampled 6 feet above oil)	.....	.....	.....	4.3	.....	.....	.....	.....	2.2	Do.
59°-60° B. gasoline (taken from top of tank)	.....	.....	.....	.....	5.5	.....	.....	.....	9.7	Explosive when diluted with air.
Do	.....	.....	.....	.....	5.5	.....	.....	.....	9.6	Do.
Storage tank; finished gasoline (sampled 2 ft. under roof)	.....	.....	.....	.....	5.2	.....	.....	.....	3.0	Explosive.
High-grade gasoline (sampled 6 inches above liquid)	.....	.....	.....	4.0	.....	.....	.....	.....	93.4	Explosive when diluted with air.
High-grade gasoline; some oil (sampled 4 ft. above liquid)	.....	.....	.....	3.8	.....	.....	.....	.....	90.2	Do.
High-grade gasoline; some oil (sampled at top of tank)	.....	.....	.....	3.9	.....	.....	.....	.....	56.9	Do.
80° B. casing-head gasoline (sampled at top of tank)	.....	.....	.....	4.1	.....	.....	.....	.....	83.6	Do.
Do	.....	.....	.....	4.1	.....	.....	.....	.....	80.4	Do.
Refined kerosene:										
Tank contained 6 in. of oil (sampled at middle of tank)	.....	.....	.....	.....	.....	.....	.....	10.0	.2	Not explosive.
Do	.....	.....	.....	.....	.....	.....	.....	10.0	.1	Do.
Tank contained 6 inches of oil (sampled 3 feet above oil)	.....	.....	.....	.....	.....	.....	.....	11.0	.1	Do.
Do	.....	.....	.....	.....	.....	.....	.....	11.2	.1	Do.
Tank had been used for receiving cracked gas oil from crude stills (sampled at side of tank 4 feet above bottom 6 inches above oil).	.....	.....	.....	.....	5.2	.....	.....	.....	3.8	Explosive.
Do	.....	.....	.....	.....	5.3	.....	.....	.....	3.6	Do.
Gas-oil distillate; probably had some naphtha in it; around cracking temperature.	.....	2.4	.....	.....	.....	.....	.....	.....	37.2	Explosive when diluted with air.
Straight-run gas oil	.....	.....	3.6	.....	.....	.....	.....	.....	1.7	Explosive.
Fuel oil direct from coke stills (sampled 2 feet above oil)	.....	.....	.....	.....	5.0	.....	.....	.....	.71	Not explosive.
Fuel oil steamed continuously; temperature, 116° F.	.....	.....	.....	.....	.....	.....	.....	10.0	.21	Do.
Test distillate, crude burning oil; similar to kerosene (sampled 6 inches above oil).	.....	.....	3.2	.....	.....	.....	.....	.....	1.25	Do.
Residuals left in tank after steaming and ventilating; tank had been used to receive crude naphtha from crude stills:										
Sampled 4 feet from bottom and 4 feet from side opposite lower manhole.	.....	.....	.....	.....	.....	.....	.....	11.6	.01	Do.
Do	.....	.....	.....	.....	.....	.....	.....	12.0	.01	Do.
Same tank but sampled 10 inches above center of tank.	.....	.....	.....	.....	.....	.....	6.7	.....	.80	Do.
Do	.....	.....	.....	.....	.....	.....	6.9	.....	.75	Do.

The temperature at which the above samples were taken varied from about 32° to 100° F. Exact data as to the temperature of each gas when sampled in many cases were not available.

*For convenience in reference the common names of the several hydrocarbons are given as follows: CH_4, methane; C_2H_6, ethane; C_3H_8, propane; C_4H_{10}, butane; C_5H_{12}, pentane; C_6H_{14}, hexane; C_7H_{16}, heptane.

range from those with two carbon atoms in the molecule, ethane (C_2H_6), to those with 12 carbon atoms, duodecane ($C_{12}H_{26}$). The combustible content varies from only a trace (0.01 per cent) to 93.4 per cent. The data also show that two types of combustibles are present, as follows:

1. Gases of lower molecular weight, such as methane, ethane, propane, and butane, dissolved in the crude petroleum and its products. These gases are liberated during the first part of the distillation processes, or during the weathering of the petroleum, etc. The proportions of these gases present may vary from a trace to high percentages.

2. Vapors of higher molecular weight from the distillates: A majority of the samples analyzed showed vapors having an average composition corresponding to hexane and heptane, and varied from pentane (C_5H_{12}) to duodecane ($C_{12}H_{26}$).

Inspection of the results shows that the vapors having 10 or more carbon atoms to the molecule are never present in sufficient quantities at ordinary temperatures to produce explosive mixtures, the highest proportion being 0.21 per cent. The average number of carbon atoms in the molecule must be eight or less for the hydrocarbon vapors to have sufficient vapor pressure to produce explosive mixtures at temperatures not exceeding 100° F.

From the data given it is seen that the safety engineer may encounter combustible gases and vapors from ethane to octane which may produce explosive mixtures at ordinary temperatures.

Explosive Limits of Gases and Vapors.

A flame becomes self-propagating through a combustible vapor and air mixture when enough of the combustible vapor is present to cause combustion to spread through the mixture from a given point of ignition. Under these conditions, flame is propagated from layer to layer of the mixture without the continued presence of the source of heat that started the flammation. A mixture of this character is obviously flammable; however, if this flammable mixture is mixed with additional air, the concentration of the combustible vapor present will be reduced to the point at which flame will no longer propagate. The explosive limit (or limit of flammability) then, is the borderline composition of the mixture; a slight change in one direction or the other produces a mixture that is accordingly flammable or non-flammable.

The amount of combustible gas present is the factor that determines the lower limit—that is to say, when the concentration of combustible gas becomes just sufficient to liberate enough heat by the burning layer to ignite the next layer, and thus propagate flame through the entire mixture, the lower explosive limit is said to have been reached.

Further addition of the combustible gas to the mixture causes proportionately greater liberation of heat for a given volume and great explosive violence when the mixture is ignited. If still more combustible gas is added to the mixture, the amount present ultimately becomes so large and the amount of oxygen present in the added air so small that the heat liberated is again just sufficient to ignite the next adjacent layer. At this point the upper limit is reached.

Factors Affecting the Limits of Flammability.

Source of Ignition.

When a source of heat of sufficient intensity and size is introduced into a mixture below the lower explosive limit, some combustion occurs at the point of application of heat. This usually is visible as a "cap" of flame and may attain sizable dimensions if the source of heat is sufficient. For example, a cap is produced in a flame safety lamp when it is brought into a mine atmosphere containing methane; if the proportion of methane is sufficient, balls of flame may become detached and rise some distance from the flame of the lamp. Such flames are not self-propagating because they are extinguished when the influence of the source of ignition is removed. Obviously, then, the source of ignition must be sufficiently intense to insure ignition. An intense source of ignition introduced into a mixture incapable of propagating flame will flame more mixture (produce a larger cap) than a weaker source. Aside from this, the source of ignition has no effect on the observations when the tests are carried out in an apparatus of the proper dimensions. The true test of an explosive mixture is whether or not it continues to propagate flame after the influence of the source of ignition has been dissipated.

Direction of Flame Propagation.

There is a difference in the explosive limits, depending on the direction in which the flame is propagated. When a source of ignition, such as a flame, is introduced into a flammable mixture, flame tends to travel away from the source in all directions. In a large volume of mixture the form of the zone of combustion would be a spherical shell of increasing radius were it not that the hot products of combustion tend to rise and thus introduce convection currents. Flame cannot travel downward when the upward movement of the heated gases, due to convection, is faster than the speed of flame in a still mixture, as happens in weak mixtures near the limits of flammability. Hence, near each limit there is a range of mixtures that will propagate flame upward but not downward. These, however, should be considered as explosive mixtures, because if they are ignited at the bottom, flame will propagate entirely through the mixture to the top. The limit found for propagation of flame in an upward direction may be considered safe, because if mixtures do not propagate flame in this direction the mixture may be considered safe for all other directions of flame propagation.

Size of Container.

As the propagation of flame depends on the transfer of energy from the burned to the neighboring unburned layer of gas and in a limit mixture the amount of energy available for transfer is just sufficient for maintenance of flame propagation, anything that reduces the available energy will affect the limits. Hence, the vessel in which the experiments are carried out should be large enough to eliminate practically the cooling effect of the walls and long enough for the observer to ascertain whether the flame continues to propagate

after the initial impulse from the igniting source has dissipated. The observed limits of flammability are widened as tube diameter is increased—rapidly at first and more slowly afterwards—so that increase of diameter above 5 cm. (approximately 2 in.) rarely shows more than a few tenths of 1 per cent in the range of flammability.

Temperature and Pressure Variations.

The normal variations of temperature and pressure have no appreciable effect on the explosive limits, and the data given here should apply for all conditions of temperature and pressure that could be endured by a worker. Greatly increased temperatures (200° F. or more above atmospheric temperature) cause some variations in the limits, and increased pressures (10 atmospheres or more above atmospheric) also produce marked changes.

Material of Which Containing Vessel Is Made.

In narrow vessels the composition of the containing vessel has some effect on the results obtained. For example: lead or copper containers give narrower limits than similar vessels of glass, because of the greater thermal conductivity of these metals.

Manner of Conducting Tests.

If the experiments are conducted in closed tubes, the pressure does not remain constant; variations of pressure during the progress of the flame influence the limit results observed, and these may vary somewhat from one vessel to another.

Turbulence.

In a few tests it has been found that the lower limit is somewhat reduced when turbulence is imparted to the mixture. Turbulence may be imparted by means of a fan, or it may be induced during the progress of the flame if the mixture is fired from the closed to the open end of a tube by the expanding hot gases, which produce a rapid movement of the unburned mixture toward the open end of the tube. The limit determined in this way may be a few tenths of 1 per cent lower than those observed by firing from the open end when the mixture is quiescent in front of the flame.

Apparatus for Determining Explosive Limits.

Desirable Characteristics.

To meet the conditions described and to give results that would most closely approximate conditions in mining and industrial fields, tests were made in an apparatus similar to that used by Coward and Hartwell[2] and the same as that used by Coward and others[3] in similar tests.

The experimental apparatus possessed the following requisites: (1) A tube large enough in diameter to eliminate as much as possible the cooling

[2]Coward, H. F., and Hartwell, F. J., Extinction of Methane Flames by Diluent Gases. Jour. Chem. Soc., Vol. 129, 1926, p. 1522.

[3]Coward, H. F., Jones, G. W., Dunkle, C. G., and Hess, B. E., The Explosibility of Methane and Natural Gas. Coop. Bull. 30 (U. S. Bureau of Mines and Carnegie Institute of Technology), 1927, pp. 8-12.

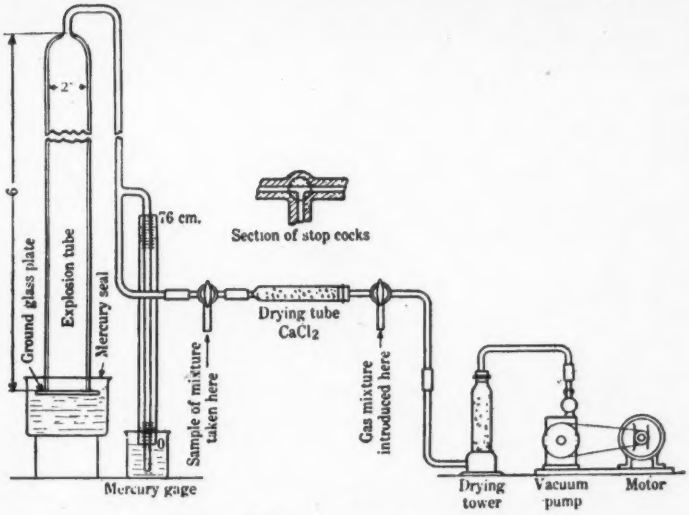


Fig. 1. Flame propagation apparatus.

effect of the wall; (2) a tube long enough for the observer to ascertain whether true propagation takes place and continues after the effect due to the ignition source had been dissipated; (3) means of ignition by a flame, which has been found to be most suitable for igniting gases of this nature; and (4) means for conducting tests under conditions of atmospheric temperature and pressure.

Apparatus Used.

The apparatus (Fig. 1) consisted of a cylindrical glass tube 2 inches (5 cm.) in diameter and 6 feet (1.8 meters) long, placed in a vertical position. The gas mixture was ignited from the lower end, and propagation of flame took place in an upward direction. Glass shell tubing, fused to the top, connected with a calcium chloride drying tube, as shown in Fig. 1. Three-way T-bore capillary stopcocks were connected at each end of the drying tube, from which connection was made to another drying tower and Hi-Vac pump. A manometer was sealed to the glass tube leading from the explosion tube. The bottom of the explosion tube was sealed with a ground-glass plate, slightly coated with vaseline, around which was placed a mercury seal to guard further against leakage. (See Fig. 1.)

Test Procedure.

In conducting a test the apparatus was evacuated by the pump until the manometer on the apparatus failed to rise farther after 15 minutes of evacuation and registered to within 1 mm. of the prevailing barometric pressure at

Table 2.—Combustion data and explosive limits of the hydrocarbon gases existing in petroleum vapors.

1	2	3	4	5	6	7	8	9	10	11	12
Hydrocarbons	Formula	Molecular weight	Chemical reaction when burned with oxygen (air)	Volumes required for complete combustion		Products of combustion per volume of gas burned			Contraction produced when one volume of gas is burned	Explosive limits in air [a]	
				O_2	Air	CO_2	H_2O vapor	N_2		Lower	Higher
Methane	CH_4	16.03	$CH_4+2O_2=CO_2+2H_2O$	2.0	9.50	1.0	2.0	7.56	2.0	5.0	15.0
Ethane	C_2H_6	30.05	$C_2H_6+3\frac{1}{2}O_2=2CO_2+3H_2O$	3.5	16.72	2.0	3.0	13.23	2.5	3.2	12.5
Propane	C_3H_8	44.06	$C_3H_8+5O_2=3CO_2+4H_2O$	5.0	23.89	3.0	4.0	18.90	3.0	2.4	9.5
Butane	C_4H_{10}	58.08	$C_4H_{10}+6\frac{1}{2}O_2=4CO_2+5H_2O$	6.5	31.06	4.0	5.0	24.57	3.5	1.9	8.5
Pentane	C_5H_{12}	72.10	$C_5H_{12}+8O_2=5CO_2+6H_2O$	8.0	38.22	5.0	6.0	30.24	4.0	1.4	8.0
Hexane	C_6H_{14}	86.11	$C_6H_{14}+9\frac{1}{2}O_2=6CO_2+7H_2O$	9.5	45.39	6.0	7.0	35.91	4.5	1.3	—
Heptane	C_7H_{16}	100.13	$C_7H_{16}+11O_2=7CO_2+8H_2O$	11.0	52.56	7.0	8.0	41.58	5.0	1.1	—
Octane	C_8H_{18}	114.14	$C_8H_{18}+12\frac{1}{2}O_2=8CO_2+9H_2O$	12.5	59.72	8.0	9.0	47.25	5.5	1.0	—

[a] See U. S. Bureau of Mines Bulletin 279, Limits of Inflammability of Gases and Vapors, by H. F. Coward and G. W. Jones, for original references for values quoted.

the time of the experiment. When the apparatus had been sufficiently evacuated, the prepared gas mixture was introduced through the right-hand cock (see Fig. 1) until the pressure was slightly above atmospheric, as indicated on the manometer. The excess of gas was then released by connecting a water seal (not shown in the drawing) to the left-hand three-way stopcock and opening to the outside air. This procedure was followed to insure that the gas in the explosion tube was at atmospheric pressure when the test was made. The mercury seal was then removed, and the mixture was tested for explosibility by sliding off the ground-glass plate and at the same time passing the flame from an alcohol lamp across the open end of the tube. The mode of propagation was then observed. A mixture close to the lower or upper limit may propagate flame a short distance because of the heat imparted to it by the flame used for ignition. By this method a mixture was found by trial that would just propagate flame to the top. It was then changed slightly until flame would no longer propagate. The average of these two values was then taken as the limit mixture.

Table 2 following gives combustion data and the explosive or flammable limits of the combustible vapors ranging from methane to octane. These are the ones of most importance in connection with explosion hazards as indicated in Table 1.

As the predominating hydrocarbons vary from ethane to heptane, it is seen that the lower and higher explosive limits may range from about 1.1 to 12.5 per cent by volume for petroleum vapors in air. Unless the average carbon content of the vapors is known, the gases should be considered flammable if the amounts of combustible vapor lie within the limits given above.

Calculation of Explosive Limits from Gas Analysis.

If means of analyzing the gas mixtures in a given space is available, the lower limit of the mixture can be fairly closely calculated from a gas analysis alone. When a combustible gas or vapor is analyzed, the combustible is burned in an excess of oxygen either by exploding in the apparatus, or by slow combustion, by passing the mixture over a glowing platinum wire. In either case, the contraction due to the burning or explosion is noted and the carbon dioxide produced is also determined. Columns 7 and 10 of Table 2 give the amounts of carbon dioxide and of contraction produced by the different hydrocarbon vapors. The ratio of the contraction to the carbon dioxide can be used for determining the lower limit of flammability of the mixture in question as shown in Figure 2. It is only necessary to divide the contraction by the carbon dioxide produced to obtain the ratio, then, using this value read direct on the curve in Fig. 2 the lower limit of flammability of the mixture in question. This curve was obtained experimentally by Coward and others (cited) and shows that calculated and determined values check closely for all saturated hydrocarbons tested.

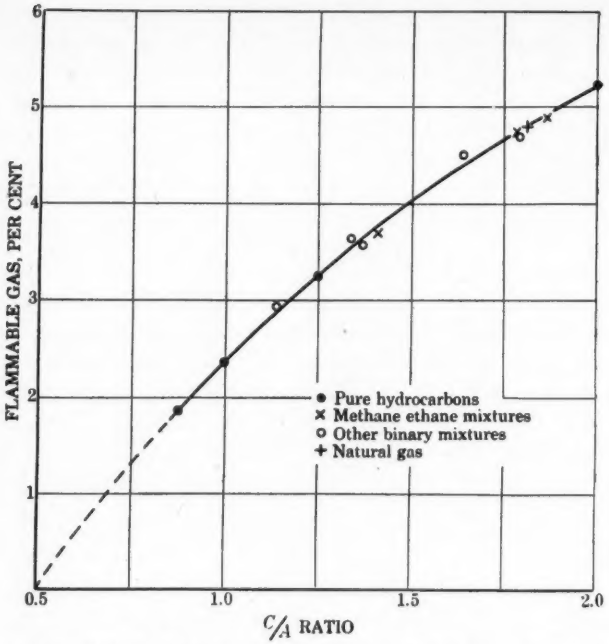


Fig. 2. Variations of lower explosive limit with C/A ratio (obtained from Table 2 by dividing column 10 by column 7).

Prevention of Explosion by the Addition of Inert Gases.

Generally speaking, three factors are essential for the development of gas explosions: (1) combustible vapors in the proper proportions; (2) sufficient oxygen; and (3) adequate sources of ignition. The elimination or proper control of any one of these may be used as a means of preventing explosions.

Ignition sources are so prevalent and varied that it is almost impossible to eliminate explosion hazards by control of this factor. Static charges, such as lightning, or sparks, and open flames are the two most prevalent sources of ignition.

Explosions may be prevented by keeping the oxygen content of the mixtures below a given percentage, depending upon the hydrocarbon vapors present. Oxygen reduction can most easily be obtained by adding inert gases such as nitrogen or carbon dioxide, or both. The extent to which the oxygen content must be reduced also depends upon whether the inert gas is nitrogen or carbon dioxide. Table 3 gives the oxygen percentages below which explosions are impossible for several combustible gases and vapors, when either nitrogen or carbon dioxide is added. Quite different values may be obtained with other inert gases.

The table gives the percentage of oxygen which must not be exceeded if explosions are to be prevented by the addition of inert gases. Values for only hydrogen, carbon monoxide, ethylene, methane, and ethane (nitrogen only) are available at the present time for tests made with upward propagation of flame in a 2-inch tube 6 feet in length, as given in this report. Tests have not been made for most of the heavy hydrocarbon vapors, but values for these vapors may be predicted from results obtained with methane and ethane. These values may require some revision when tests on these other gases and vapors are completed. It is fairly safe to state that if nitrogen is added to any saturated hydrocarbon-air mixture until the oxygen content is below 11.0 per cent, the mixture will not be explosive. If carbon dioxide is added alone, such additions should be continued until the oxygen content of the atmosphere is below 13.0 per cent. If flue gas is used (12.0 per cent carbon dioxide and 88 per cent nitrogen) such additions should be continued until the oxygen content is below 11.5 per cent.

Table 3.—Effect of inert gases and low oxygen content on explosibility.

Combustible gas or vapor	Formula	Per cent of oxygen by volume in mixture below which explosions are impossible at ordinary temperatures and pressures			Volumes of inert gas necessary to render one volume of combustible non-explosive under all conditions of dilution with air at ordinary temperatures and pressures		
		Nitrogen	Carbon dioxide	Flue gas	Nitrogen	Carbon dioxide	Flue gas
Hydrogen	H_2	5.0	5.9	5.1	16.5	10.2	11.0
Carbon monoxide.	CO	5.6	5.9	5.6	4.1	2.2	2.4
Ethylene	C_2H_4	10.0	11.7	10.2	15.3	9.0	9.8
Methane	CH_4	12.1	14.6	12.3	6.0	3.2	3.5
Ethane	C_2H_6	11.0	—	—	12.8	—	—

The fact that the oxygen is kept below the values given in the foregoing table does not guarantee that explosions are impossible, for if air gains entrance to the mixture, or if by accident the gases leak out in the open, such mixtures, if they contain large excesses of hydrocarbon vapors, will again become explosive when the proper amount of air has mixed with them.

To insure safety under all conditions of admixture with air at ordinary temperatures and pressures, it is necessary to add inert gases in the proportions given in the last three columns of Table 3. It is seen that the amounts vary over a wide range and that such values have not been determined for the heavy hydrocarbon vapors. Such tests are now in progress at the Pittsburgh Experiment Station of the Bureau of Mines to obtain this information.

For methane it is seen that when 6 volumes of nitrogen is added to 1 volume of methane, the methane is rendered entirely non-explosive, regardless

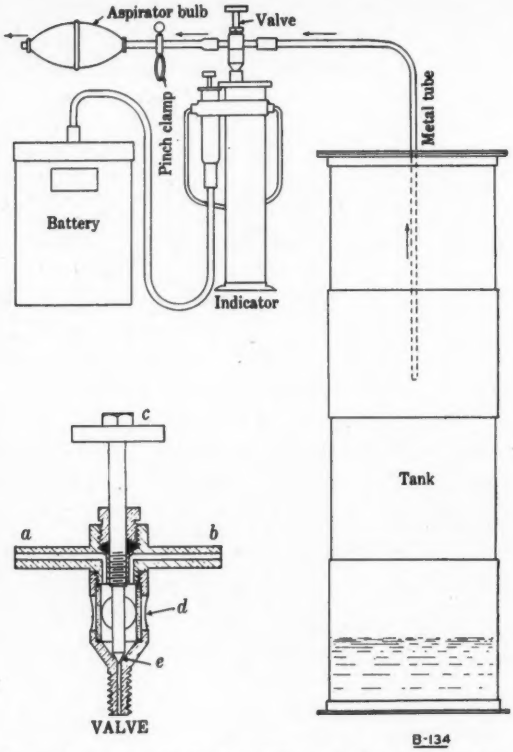


Fig. 3. Apparatus and method of sampling petroleum vapors from tanks.

of what proportions of air may later be mixed with it, whereas under similar conditions, 16.5 volumes of nitrogen is required to render 1 volume of hydrogen non-explosive. The other combustibles vary as given in the table.

Apparatus for Testing the Explosibility of Hydrocarbon Vapors.

The Burrell methane indicator has been used to determine the amounts of hydrocarbon vapors in confined spaces as reported by Jones and Yant (cited). When used for this purpose a special scale giving the relative flammability replaces the regular methane scale, and a special attachment (Fig. 3) is provided with the indicator so that samples of the atmosphere may be taken from places where it is impossible or inadvisable to enter. The procedure of making tests follows that described in previous reports for testing for methane in mine atmospheres.

The apparatus has its limitations in that it shows percentages only up to

Fig. 4. U.C.C. Combustible Gas Detector.

the lower explosive limits. It should not be used for atmospheres which are explosive, and is of no value for atmospheres containing hydrocarbon vapors above the higher explosive limit or those containing a deficiency of oxygen.

Another device[4] has recently been developed by the Union Carbide & Chemical Corporation for the quick determination of small quantities of flammable gases and vapors. The apparatus (Fig. 4) comprises the following parts: A detector head or combustion chamber *a*, meter case *b*, and portable storage battery *c*. When a mixture of air and combustible vapor enters the combustion chamber, which is placed in the atmosphere to be tested, the gas comes in contact with a hot platinum filament, which is normally heated bright red by the electric current of the battery. Rapid combustion of the mixture takes place at the surface of the heated filament, which in turn increases the temperature and consequently raises its electrical resistance. This change of resistance causes the needle of a sensitive meter to move over a scale, which indicates the relative amounts of combustible vapors present. The advantages

[4]Mabbs, J. K., and Rowland, W. B., Portable Detector Developed for Many Combustible Gases. Chem. & Met. Eng., Vol. 36, 1929, p. 490; N.F.P.A. Quarterly, July, 1929 (Vol. 23, No. 1, p. 48).

claimed for this device are that it is rugged, dependable, portable, self-contained, easy to use, and quickly determines the percentage of combustible vapors. It appears to be especially adapted for detecting the presence of hydrocarbon vapors ranging from a trace up to the lower explosive limit; if the mixture is explosive, such mixtures are indicated by the needle oscillating continually. It has a limited value for indicating mixtures above the higher limit and is of no value for indicating mixtures deficent in oxygen.

Another device (Fig. 5) developed by engineers of the Standard Oil Co. of California, called a gasoline vapor indicator, utilizes the same principle as the U.C.C. indicator and has recently been described by H. H. Hall.[5] This device differs from the U.C.C. apparatus in that the samples of vapor-air are drawn into the instrument containing the heated filament and other mechanism with an aspirator. The apparatus is portable and detects at once very low percentages of hydrocarbon vapors. Referring to Fig. 5, a hose which leads to the point where the sample is to be taken is connected to *A*, and the bulb *B*

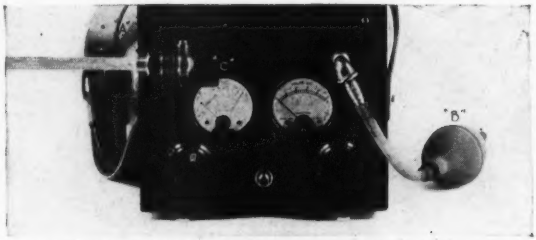


Fig. 5. Standard Oil Co. gasoline vapor indicator (top view).

is used to aspirate the sample to be tested through the hose and the apparatus. The relative amounts of hydrocarbon vapors are indicated by the deflection of the needle on dial *C*, very similar to the U.C.C. apparatus. Its main difference is that the heating element, instead of being introduced direct into the atmosphere to be tested, is some distance removed.

An apparatus (Fig. 6) developed by the U. S. Bureau of Mines, more especially for the detection of combustible gases or vapors in manholes and other underground spaces, may be used for the detection of hydrocarbon vapors. It consists of an upright removable bomb, *a*, a gage, *b*, for registering explosions, an ignition system mounted on the back of the apparatus, a tank of propane, *c*, for enriching the test mixtures, and a unit, *d*, for introducing small increments of propane to the gas mixture being tested. As the entire apparatus is not spark-proof, the bomb is detached from the apparatus and a sample taken into the bomb by aspiration. When the sample has been taken, the cocks are closed and the bomb is re-attached to the apparatus. The explo-

[5]Hall, H. H., A Simple Gasoline Vapor Indicator. Bull. Amer. Pet. Inst., Vol. 10, No. 2, section II, Jan. 3, 1929, pp. 99-104; N.F.P.A. Quarterly, April, 1929 (Vol. 22, No. 4, p. 392).

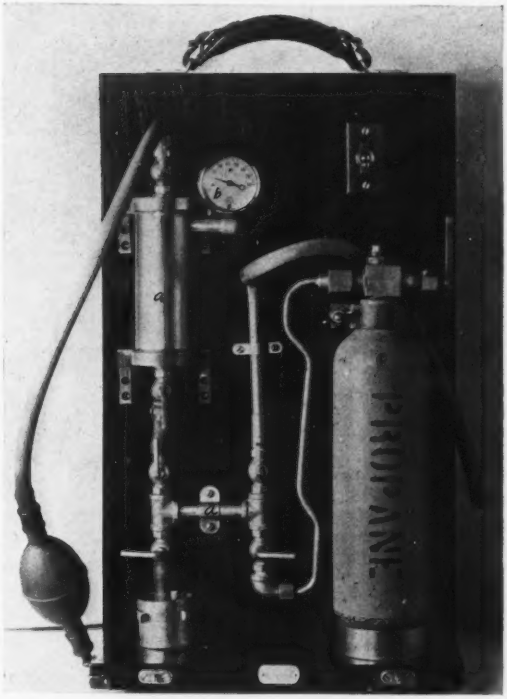


Fig. 6. Bureau of Mines Combustible Gas Detector.

sibility of the mixture is tested by passing a spark in the bomb. If the gas explodes, the needle on the gauge moves quickly, registering the pressure developed. If no explosion takes place the aspirator bulb is connected to the outlet tube and increments of propane added to the gas mixture. The instrument is calibrated so that 4, 5, or more increments of propane must be added to produce an explosive mixture with normal air. If the apparatus is calibrated to produce an explosive mixture with 4 additions of propane (this is the usual calibration), then if by tests the mixture explodes on the first addition of propane, the mixture under test is about three-fourths explosive; if it explodes on the second addition, then it is about one-half explosive; if on the third addition, it is about one-fourth explosive; and if on the fourth addition, it contains very little combustible gas. If it fails on the fourth and fifth addition of propane the atmosphere is either so deficient in oxygen that an explosion is impossible, or so much combustible vapor is present that the mixture is above the higher limit. Another sample is then taken of the gas to be tested and diluted with air. If repeated dilutions with air fail to give a mixture that

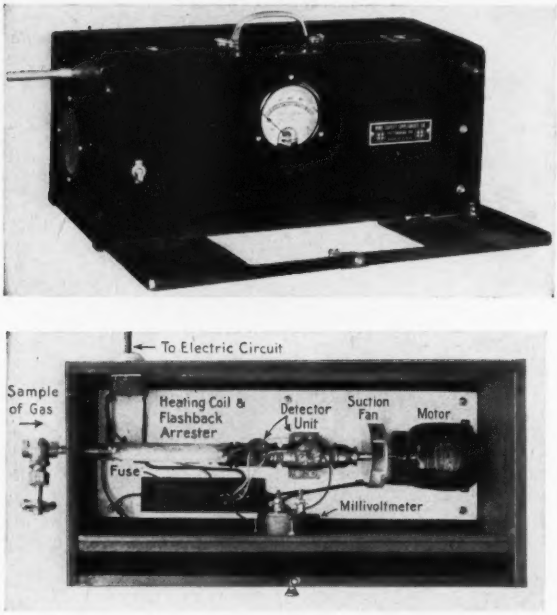


Fig. 7. The F.M. Flammable Vapor Indicator. Lower view shows instrument with cover off. The suction fan draws the sample of gas through the heating coil, flash back arrester and detector unit.

explodes, then the gas under test contains such a low percentage of oxygen that the mixture is non-explosive.

Another device by the Factory Mutual Laboratories has been developed[6] for continuously recording the relative explosibility of atmospheres, especially those at elevated temperatures. In its operation the gas is drawn through the instrument (Fig. 7) by means of a motor-operated suction fan, the motor being of a special type which maintains a constant speed irrespective of voltage fluctuations. A heating coil prevents condensation in the instrument and permits its use for vapor-air mixtures at high temperatures. The device is essentially a continuous calorimeter in that it burns the vapor and indicates the heat given off. A continuous sample of the atmosphere under test is drawn by the small fan, first through a heating coil which keeps the sample at an elevated temperature to prevent condensation, and thence through a flash-back arrester to the detector unit. Here combustion of the vapor is produced without flame by contact with a catalyst which is electrically heated to a temperature slightly less than a red heat. The increase in temperature from the combustion of the vapor is indicated on a millivoltmeter through the agency of a

[6]Flammable Vapor Indicators, N.F.P.A. Quarterly, April, 1929 (Vol. 22, No. 4, p. 390).

thermocouple located at the catalyst. By means of a chart the millivoltmeter reading may be expressed quickly in terms of the lower explosive limit concentration. On account of the low operating temperature of the detector unit and the nature of the catalyst used, the manufacturers claim an exceptionally long life for the unit and an accurate indication without special calibration for any hydrocarbon vapor.

This device differs from the ones previously described in that it is intended for more or less permanent installation in one or a few places, and must be used where electric current is available.

Conclusions.

1. Analyses of hydrocarbon gases which are liberated by petroleum and its products show that the vapors are variable in composition and may range in average composition from ethane to duodecane. The amounts present may vary from a trace to high percentages.

2. The following table represents the conclusions of the authors on the flammable limits of the several hydrocarbon gases listed.

Gas or Vapor	Per Cent by Volume Limits of Flammability Lower	Higher
Methane	5.0	15.0
Ethane	3.2	12.5
Propane	2.4	9.5
Butane	1.9	8.5
Pentane	1.4	8.0
Hexane*	1.3	—
Heptane*	1.1	—
Octane*	1.0	—

*Some investigators have reported somewhat lower minimum flammable limits in the case of hexane, heptane and octane.

3. On the basis that the average composition of the hydrocarbon vapors which may produce explosive mixtures may range from ethane to heptane, the explosive limits range from about 1.0 per cent lower to 12.5 per cent higher limit.

4. If a sample of the petroleum gas mixture whose flammability is desired is burned in any of the ordinary gas-analysis apparatus, and the ratio of the contraction produced resulting from this burning to the carbon dioxide produced is taken, the lower explosive limit can be accurately calculated by means of the curve given in this report.

5. Hydrocarbon vapors and air mixtures can be made non-explosive by adding inert gases, as nitrogen, carbon dioxide, or flue gas, to the mixture until the oxygen content is reduced below values given in this report.

6. A brief description is given of some of the portable apparatus used for determining the explosibility of hydrocarbon gases.

Manhole and Sewer Explosions.

Sewers and other underground conduits and tunnels have long been recognized by fire protection engineers as constituting a fire and explosion hazard of some severity, but the average person has but little conception of the potential danger lurking underground in all our cities. The blowing off of manhole covers, following slight explosions in sewers, is not infrequent, but, as a rule, these covers serve as vents and comparatively little damage results.

However, three explosions of considerable magnitude have occurred during the past eighteen months which have served to attract attention to this hazard and to preventive measures and legislation. These three particular explosions were those occurring in London, England, on December 21, 1928; Boston, Mass., February 14, 1929; and Newburgh, N. Y., September 16, 1929. Details of these explosions are included in the record of fires which follows.

In view of the considerable number of dangerous gases that may be present in sewers, it may seem strange that there are so few evidences of their harmful potentialities. Some of the reasons for the relative infrequency of accidents in connection with gases in sewers are:

1. The total amount of flammable gas or vapor may be too small to produce a dangerous atmosphere.
2. There may be no source of ignition even though a flammable mixture of gas and air is present.
3. Poisonous or asphyxiating gas can do no harm unless living beings are exposed to it.

However, the fact that gases may be present in sewers and may cause harm plainly indicates the necessity for taking all possible precautions, not only to safeguard workmen that are required to enter sewers, but also to prevent injury to other persons and damage to property that may be caused by explosions. In dealing with electrical conductors, every person should proceed on the assumption that they are "alive"; likewise, in connection with sewers, it should always be assumed that dangerous gases are present until definite proof to the contrary has been obtained.

The dangerous gases actually found by analysis in street manholes in different cities of the United States can be grouped into three classes: (1) poisonous, (2) suffocating, and (3) explosive, although some fall into more than one class. These gases and their principal sources, based on investigations of the U. S. Bureau of Mines, are shown in the following table:

The preparation of this article has been made possible through the coöperation of various N.F.P.A. members who have contributed fire record data and other material on the subject of manhole and sewer explosions. Among these, particular acknowledgment is made to the Travelers Insurance Co. for material taken from the Travelers *Standard*.

Principal Dangerous Gases Found in Manholes.

Name of Gas.	Properties.	Source.
Ammonia	Poisonous	Refrigerating plants.
Benzol	Poisonous—Explosive	Motor vehicles—Storage tanks.
Carbon Dioxide	Suffocating	Combustion—Decomposition.
Carbon Monoxide	Poisonous—Explosive	Mfr'd fuel gas—Flue gas—Combustion—Exhaust from motors.
Ethane	Explosive	Natural gas—Mfr'd fuel gas.
Gasoline	Poisonous—Explosive	Motor vehicles—Storage tanks.
Hydrogen	Explosive	Artificial fuel gases—Electrolysis of water.
Hydrogen Sulphide	Poisonous	Coal gas—Decomposition.
Methane	Explosive	Natural gas—Mfr'd gas—Decomposition.
Natural Gas	Suffocating	Natural gas mains.
Nitrogen	Suffocating	Combustion—Decomposition.
Sulphur Dioxide	Poisonous	Burning insulation.
Unsaturated Hydrocarbons	Explosive	Manufactured fuel gases.

In addition to the above, phosphine gas is occasionally generated in sewers. This gas is poisonous and flammable, and in addition, when impure, it has the peculiar and unusual property of taking fire spontaneously upon coming into contact with air.

It seems quite likely that phosphine may be the active agent in causing some of the explosions in sewers from undetermined cause, by which manhole covers are blown off and other damage done. A single bubble of phosphine, taking fire when it comes to the surface of the water in a sewer, might be sufficient to ignite any other flammable gas present.

As typical of conditions which may exist in the average city, a complete description was given in a bulletin issued by the Bureau of Mines dated October, 1925, of investigations of gas conditions in sewer and public utility manholes in Pittsburgh and Philadelphia. The atmosphere of 15 manholes at Pittsburgh and 12 at Philadelphia, suspected of being gaseous, was tested and explosive mixtures of gas and air were found in one manhole in the former city and two in the latter.

Gasoline and oil from filling stations, garages and automobile repair shops, and other volatile flammable liquids used in various manufacturing processes, are often discharged into sewers, and the gases from them are likely to create conditions making for the possibilities of flash fires and explosions.

A sewer explosion in Ottawa, Canada, not long ago, was attributed to this cause. One account of the disaster states that "Terrific explosions, believed to have been caused by waste gasoline leaking into the city main sewer, rocked the downtown section of Ottawa, causing the death of several persons and injury to many others. Heavy manhole covers were tossed high into the air, followed by loud reports and burst of flame."

Underwood and Underwood.

Interior of St. Martin's Chapel at Ottawa after explosion believed due to waste gasoline leaking in the city main sewer.

Ordinances and regulations prohibiting the discharge of flammable liquids into sewers have been adopted by many cities, and the number of communities having such legislation is constantly increasing.

In 1928 an interesting report was made of the results of a survey made by the Sewer Department of the District of Columbia relative to the disposition of waste crankcase oils. This survey was occasioned by the realization of the hazards brought about by large quantities of crankcase drainings entering the public sewers.

It was ascertained that these drainings usually contain gasoline in an amount sufficient to vaporize in the sewer, thereby creating a combustible gas capable of ready ignition, resulting in explosions or fire. It was also determined that the gas thus created, being heavier than the warm air inside the sewers, does not readily escape from air vents. The problem is further complicated by the ever increasing use of automobiles, resulting in a corresponding increase in the volume of waste crankcase oil for disposition.

The governing regulations of the District provided only against certain disposition being made of this oil without having considered the efficacy such regulations gave in actually excluding these oils from public sewers. This merely prohibitive regulation proved to be an entirely ineffective measure, as its enforcement depended in too great a degree upon the spirit and respect of

the public toward the intent of the regulation. While these regulations also required the maintenance of an intercepting tray by garages, it is evident that if only oil is placed in a trap, regardless of type, which is connected with the sewerage system, this oil will naturally flow into the sewers.

A questionnaire was sent out to cities throughout the country, and from the forty-six replies received the following information was obtained:

Cities prohibiting the disposal of waste oil in sewers	70%
Cities not prohibiting the disposal of waste oil in sewers	25%
Cities not making definite reply to above query	5%
Cities collecting waste crank case oil	7%
Cities in which commercial firms collect this oil to some extent	55%
Cities requiring the maintenance of intercepting garage traps	75%
Cities reporting fires or explosions in sewers	35%
Cities reporting trouble from presence of oil in sewers	65%
Cities manifesting an interest in the subject	85%

With all the information at hand, including the reports from the United States Bureau of Standards showing the value of the product, it was recommended that the plumbing regulations of the District of Columbia be revised and amended to require the maintenance by garages, filling and service stations, automobile repair shops, etc., of approved containers or underground tanks, separate and apart from garage traps, for the retention of all waste crankcase oils, the contents of the same to be removed by the occupant or operator at regular intervals or upon notice from the district authorities. Regulations for the safe transportation of this commodity were also included in the proposed amendments.

Illuminating gas sometimes escapes into sewers and manholes from leaks in underground mains and other sources, and adds to the danger. Gasoline and illuminating gas are to be feared chiefly because of their flammability, but the possibilities of poisoning and asphyxiation should be considered also, particularly in connection with illuminating gas, which contains a large amount of deadly carbon monoxide.

Great care should be taken, when testing the atmosphere of sewers, because of the varying nature of the gases that may be present. Some of the more common methods employed are rather crude, and although they might be satisfactory in testing for gas of one kind, they might, on the other hand, actually precipitate an accident if gas of another variety were present. For example, a certain foreman in charge of sewer maintenance required his men, before entering sewer manholes, to lower a lighted lantern into the sewer to discover the possible presence of carbon dioxide—the theory being that the light would be extinguished if there were sufficient gas to create an asphyxiation hazard. Evidently he failed to consider the serious possibility of the open flame igniting gasoline vapors or other flammable vapors or gases (in case any were present) and thus causing a flash fire or explosion.

Open-flame lights—such as lanterns and candles—should never be introduced into sewers, nor should smoking or lighting matches be allowed. Electric flash lamps, or incandescent lamps having vapor-proof globes with guards to prevent breakage, should be used for illuminating purposes; and care should be taken to see that the insulation on wires leading to incandescent lamps is in first-class condition.

Gas detectors of various kinds have been devised for testing the atmosphere of enclosed spaces, and the use of them for determining the presence of gases (both flammable and poisonous) in sewers, appears entirely practicable. Whether or not a gas detector is used, effective methods should be employed to insure thorough ventilation of sewers before allowing anyone to enter them. Several manhole covers in the immediate vicinity of the operations should be removed to stimulate the circulation of air, and this natural ventilation may be supplemented by introducing fans or blowers into the manholes and setting them in operation.

It would also be advisable to thoroughly flush with water the section of a sewer where work is to be done, using a fire hose attached to a hydrant. The additional volume of water supplied in this way would remove the solid organic material present (or a considerable part of it) and stop the generation of gas; and as the water would be introduced under a fairly high pressure, it would tend to set the air in the sewer in circulation, thus dissipating any gas that might be present, or diluting it so that it would no longer be dangerous.

Furthermore, whenever there is a possibility of asphyxiation or poisoning by gas that may be generated in sewers, gas masks of suitable types should be provided, and the workmen should be required to put them on and adjust them properly before entering the manholes. Life lines and life belts should also be provided.

Fire Record of Manholes and Sewers.

The fire record files of the National Fire Protection Association contain a comparatively small number of manhole and sewer explosions and fires, but those on file are, for the most part, of more than passing interest and are indicative of the potential hazard involved.

Severe Manhole and Sewer Explosions.

Minneapolis, Minn., July 30, 1921.

More than forty persons were injured and property damage amounting to approximately $50,000 was caused when a series of explosions in underground wire conduits blew up portions of paving and partially wrecked several stores.

The first explosion came at 10:15 P.M. on Saturday, July 30, 1921, when two manholes at the corner of Sixth Street and Nicollet Avenue blew up. The

manhole covers were thrown twenty feet or more into the air and there was an immediate burst of flame from the holes.

Shortly after 11 P.M. a second explosion occurred, bursting from a manhole at the northwest corner of the street and in the very midst of the crowd which had gathered. This blast tore a large hole in the pavement, demolished a cigar store and damaged a jewelry store adjoining. It was here that most of the injuries occurred, the greater number due to flying glass. Two persons fell into the hole in the pavement, and the contents of the store windows were hurled into the street. Flames shot from the hole and were followed by another slight blast.

The third explosion occurred halfway up the block in front of the Stiles Building, a five-story structure with jewelry stores on the first floor and offices above. This explosion caused considerable property damage, but no one was injured. Every window in the building from the first floor to the roof was blown out, and window stocks in the stores on the first floor were blown into the street.

A fourth explosion occurred at 12:15 A.M. on the 31st, at a point above the Stiles Building, but little damage was done, due possibly to the fact that the vent was closed. The fire continued to rage in the conduit with considerable intensity, shooting in jets from the manholes and filling the street with acrid smoke and fumes from the burning insulations. The firemen were loath to use water because they were afraid of causing a steam explosion in the confined tunnel.

Fire was also started in the basement of the Donaldson Building at Nicollet and Seventh Street by gas and flames which entered through conduits leading into the building. The blaze was confined to the shoe department of the store and the greatest damage was done by water.

The various outbreaks of fire were considered under control at 1:30 A.M., and at this time the electric power of the entire district was cut off to prevent further explosions. A police cordon was thrown about the district to prevent possible looting induced by the complete darkness due to cutting off the lights.

Records of the fire department, examined after the explosion, indicated that trouble in the manhole at Sixth Street had been brewing for at least forty-eight hours before the explosion occurred. On Thursday, the 28th, at 6:19 P.M., the fire department was called to the corner by citizens who reported that the manhole was "on fire." The cover was removed and the firemen examined the cables. Aside from a little smoke they could discover no trouble and reported the matter to the electric company.

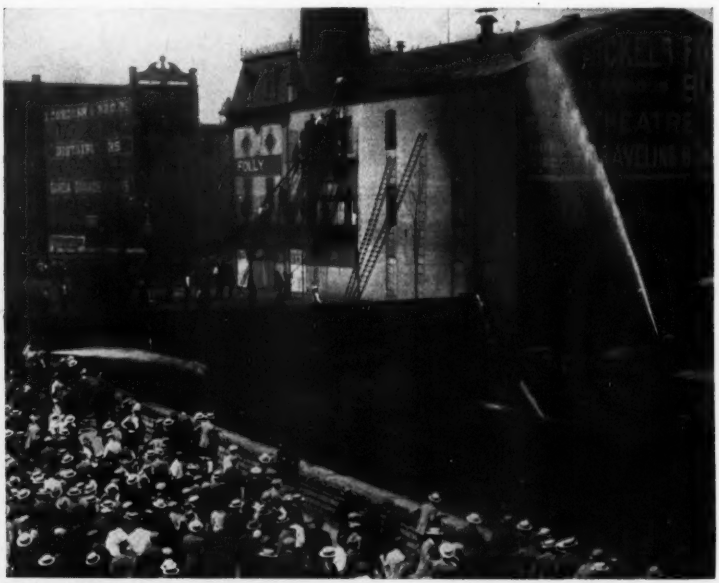
Again on Friday afternoon a proprietor of a store in the vicinity called the fire department and said the manhole was still smoking. A lineman of the fire department and an employee of the electric company were detailed to inspect the cables. Both reported that they could not discover any trouble.

Several theories as to the cause of the explosions were advanced. The most plausible of these seems to be that the porcelain division between two of the insulated cables cracked, the insulation broken and a short circuit caused. The resulting sparks must have ignited stagnant sewer gas. The first smoke must have been caused by smouldering insulation, the heat of which cracked more porcelain partitions until sufficient fire and gas were present in one chamber to cause the explosion.

Baltimore, Md., June 8, 1926.

At 1:42 P.M. on June 8, 1926, a citizen, walking on West Falls Avenue near Lombard Street, was observed to light a cigar or cigarette and throw a burning match over the abutment wall into the open section of Jones Falls (a storm water drain of three tubes above the open section), which extends from Baltimore Street south to the harbor front, a distance of three city blocks. A flash followed immediately, and, in a few seconds, practically the entire surface of the open section was covered with flames which leaped fifty feet or more in the air and sent up large clouds of black smoke typical of an oil fire.

An alarm was sounded, and when the fire department arrived it was



Fire Prevention Year Book.

Baltimore, Md. At this point the fire extended from the open storm-water sewer into the tubes under the streets. It continued for 14 city blocks, blowing off manhole plates along the way, and at the most distant points with such force as to blow all the glass and framework from the front of a store building.

found that the fire had extended into the east tube of the covered section of the falls north of Baltimore Street. Explosions took place in this tube, extending from Baltimore Street to Eager Street, and taking an eastward course to the corner of Graves Street, where the force of the explosions was such that manhole plates were blown off and the front of one building was stripped of woodwork and glass.

Smoke and flame were shot in heavy volumes from the numerous sewer openings for storm water drainage on the Fallsway for the distance of more than a mile, endangering automobiles and buildings; and smoke also backed up through clear water drains into many buildings along the Fallsway, causing calls from citizens for investigation by the fire department. The force of the explosions and the heavy smoke emitting over this section caused semi-panic conditions for a few minutes.

Chief Emrich of the fire department sounded three alarms and distributed apparatus along the entire affected area. The four foam type chemical engines of the department were also sent for, as it was not known what quantity of burnable oils was behind the fire.

The fire was most intense at the point of opening of the sewer at Baltimore Street into the uncovered stream, flames sweeping over the top of the Folly Theatre and igniting that building at the roof and passing through a window into the section under the stage. Fortunately the fire department was able to check the fires in this building with comparatively light loss.

After the first general flare, which lasted approximately three to five minutes, sections of burning oil floating down the surface of the open falls passed under the Lombard Street and Pratt Street bridges, setting fire to those structures. The fire department devoted itself to throwing streams of water into the burning sections of oil in order to break them up and cause a more scattered and rapid burning.

The fire was of such a nature that the fire department was forced to rely largely upon the blaze consuming the oils, and only the fact that the destruction of the oils on the surface of the water was fairly well completed before it reached the section of the falls below Pratt Street prevented a serious fire on the city water front.

Investigations made immediately following the fire, through sewer openings, showed a decided trace of light oils and odor of flammable liquids. While the fire was still burning in the covered section of the falls, the fire department found employees of an automobile washing establishment cleaning cars by a method of water and vaporized kerosene, which was running down in a so-called clear water drain leading directly into the east tube of the falls. A considerable quantity of crankcase drainings was found piled near one of these openings and was also washing into the sewer inlet. Two attendants and the proprietors of this establishment were placed under arrest,

charged with violating city ordinances by allowing burnable oils to pass into the sewer inlet.

This particular operation was not of sufficient volume, in the opinion of the fire department officials, to have caused in its entirety the fire in question, but was undoubtedly contributory. This class of washing and disposal of crankcase drainings and general waste oils from garages and filling stations by emptying into the sewerage system may have been a considerable factor in the agitation of the fire in question.

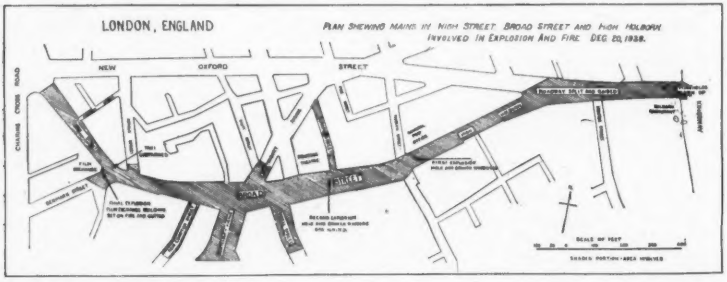
London, England, Dec. 20, 1928.

A half-mile long triangular area in the heart of London presented the appearance of a shelled town in war-time, after a series of explosions which occurred in an old tunnel used as a conduit for electric wires. One man was killed, thirteen were injured, and a property loss estimated at more than half a million dollars was occasioned.

The tunnel in which the blast occurred was an old iron-plate tunnel, built more than sixty years ago and originally used as a pneumatic-tube package delivery system. Years ago it was taken over by the post office department, which also operates the telephone and telegraph systems, and used as a conduit for wires. It was one of many conduits, gas mains, water mains and sewers which virtually honeycomb the city beneath the surface.

At about 7:45 A.M. three workmen arrived at a manhole in High Holborn to start the motor-driven fan located in the tube in order to clear it of sewer gas. This fan, or blower, had been installed as a result of workmen being overcome by gas or foul air in November, 1926. To operate the blower it was necessary to enter the tube and connect a plug attached to the lead from the blower to the socket at the switch.

The cover of the manhole was removed and one of the workmen descended the iron ladder to attach the plug to the socket in the tube. Scarcely



The area affected by the London explosion. The shaded streets indicate the area in which the damage was done.

had he gotten out of sight when the other workmen heard a "boom" and a flash of flame rose almost to the top of the manhole and then drew out. As the flame receded the workman in the tube rushed to the ladder and as he reached the top of the manhole he was caught by the blast of an explosion and enveloped in flame. He was so badly burned that he died six days later. The roof of the manhole was wrecked.

Almost simultaneous with the first appearance of flame in the tube and before the first violent explosion, the flash of fire traveled along the tube in both directions. Eastward a wave of explosive violence was reached after the flame had traveled about 90 yards, as was shown by the wrecking of the tube beyond this distance for a length of 30 yards. The surface effect was the projection high into the air of two heavy manhole covers at the eastern extremity of the tube and the splitting of the surface of the roadway.

Westward the flame, starting from the post office manhole, similarly reached explosive violence after traveling for about 90 yards. In this direction, however, the violence did not diminish, as the whole of the tube from this 90-yard point to its western extremity at St. Giles' Circus was wrecked.

Great havoc was made of the roadway. Instead of the momentary explosion which occurred eastward of the post office manhole, underground surgings continued for possibly as long as 30 seconds, while the foot-thick concrete roadway rose and fell—flowing, as one witness described it, like water—finally coming to rest in some places wedged up above the original road level, and in others fallen down into the cavity formerly occupied by the tube. Mingled with surging and rending sounds were two or perhaps three distinct reports in quick succession, which no doubt issued from places such as the manhole chamber on the tube opposite New Compton Street, where gases found release by bursting the surface.

In High Street near Denmark Street a water main was broken and water quickly filled up cavities and flooded neighboring vaults. A "cloud of dense, very dark grayish smoke" indicated that the water had the fortunate effect of smothering flames of escaping gas burning under the wreckage of the road. In this area it happened that the tube lay near the north side of the road. The result was that a length of the footway was wrecked and damaged vaults were exposed to view.

Fire at Grape Street.

The prolonging of the effects of the series of explosions in this westward direction was no doubt due to the fracture of gas mains lying close to the tube. Unlimited fresh supplies of gas would thus have become available and mixtures of varying strengths been formed in cavities still remaining in the tube or made by the original explosion. A good illustration of this effect was an explosion which occurred about three minutes after what may be called the original thirty-second series. This explosion occurred at the junction of

International.

Part of the wreckage of Holborn High Street and an overturned taxi, following an underground explosion, London, England.

Grape Street and Broad Street close to Prince's Theatre, and appears to have been due to the destruction by the first explosion of the junction of a four-inch with an eight-inch gas main.

The escaping gas no doubt formed an explosive mixture in a cavity made by the first explosion, and this mixture became ignited by residual flames. A large hole was blown in the road and the escaping gas was ignited and continued to burn for several hours. It may be said that, with the exception of the fire which occurred about four hours later and is described in the next paragraph, this gas escape at Grape Street was the only one that caught fire and remained alight. Large volumes of gas escaped into the air, and but for the energetic measures taken by the police and local authority in controlling the area and giving warning of the danger of smoking and naked lights further serious results would probably have followed. As it was, five persons, including a station officer of the fire brigade, were affected by the gas. This fire was extinguished by isolating the gas mains feeding it.

Fire at Denmark Street.

Shortly after 12:30 P.M. a fire broke out in or near the building occupied by Overseas Film Limited and British Acoustic Films Limited at the corner of High Street and Denmark Street. This outbreak occurred immediately after the extinction of the fire at Grape Street, but the fact that the interval between the occurrences was very short was, in the opinion of the investigating committee, merely a coincidence.

It is not altogether clear from the evidence where the Denmark Street fire originated. There is some evidence which suggests that it started in the

International.

London, England. Film exchange in flames as result of explosion and fire which occurred in underground conduit for electric cables.

basement of the building and then spread to the gas escaping in the roadway, but none of the witnesses appear to have been in a good enough position to determine definitely whether the fire started in the basement of the building or in the roadway. The gas mains in the neighborhood were particularly badly fractured and gas was pouring out in large volumes and no doubt filled up adjacent cavities such as manholes and basements, and it is no matter for surprise that in some way or another it should have been ignited.

In the building were stored about three tons of nitrocellulose films, much of it in the basement which extended under the street. The fire rapidly consumed the films and caused great damage to the building. The gas escaping through the damaged roadway continued to burn until about 2:00 P.M. on December 21st, when the isolation of the gas mains was completed. So far as we have been able to ascertain there were no other fires or explosions.

Aside from the specific damage indicated in the foregoing, considerable injury resulted to electric power and light ducts, and more than twenty fractures were suffered by water mains. There was also serious damage done to private vaults and cellars under the road, many of those in High Street being blown in, and minor damage was done to windows and house fronts.

The cause of the blast was attributed to the ignition of fermentation gases in the tunnel. The gas, akin to methane or marsh gas, originated from decomposing material in the surrounding ground. It filtered into the tunnel through the rusting iron plates until the entire tube was charged, waiting a

spark to touch it off. The socket or receptacle for the blower lead plug had apparently not been touched and it seems unlikely that ignition could have been due to a spark at this point. Evidence was presented at the hearing before the commission of inquiry indicating that the employee who entered the manhole struck a light, using a cigarette lighter, as a lighter was found in the débris around the hole.

It seems likely, then, that the ignition of the gas was due to carelessness on the part of the workman, and in their summary of the explosion the commission of inquiry state that even though no evidence had been presented relative to the cigarette lighter their conclusion would be that the ignition of the gas was caused by some action on the part of one of the three workmen.

Boston, Mass., February 14, 1929.

Four heavy explosions accompanied by numerous lesser blasts sent a total of twenty-nine persons to hospitals, resulted in minor injuries to a score of others, damaged the fronts of sixteen buildings, frightened hundreds of store employees and late afternoon shoppers in the vicinity of Summer and Chauncy Streets.

The first heavy explosion occurred shortly before 5:20 P.M. in the underground electrical distribution system, and was followed by two others within

Frank H. Colby, Boston Transcript.

Twenty-nine people were injured, sixteen store fronts were damaged, and the district was plunged into darkness when a short circuit occurred in an electric cable conduit in the shopping district of Boston, February 14, 1929.

twenty minutes. More than twenty-five manhole covers, within a radius of half a mile from the point where the greatest damage was done, were thrown into the air and buildings in the area were plunged into darkness. Windows on the street floors of most of the stores were smashed and more than a dozen windows on the upper floors of some of the buildings were broken. Injuries to persons were due to flying glass and being trampled upon in an endeavor to escape.

The fourth and final explosion occurred at four o'clock in the morning. Three Edison Company employees were working in a conduit below street level withdrawing damaged cable when accumulated gas exploded with a flash of flame. The workmen were burned about the face and hands.

The exact cause of the explosions was not made public, but statements made by officials immediately following the occurrence indicated the following possibilities:

1. Illuminating gas or sewer gas may have seeped into the conduit and there ignited from a spark or short circuit.

2. When sewers which drain garages and commercial establishments receive gasoline or other combustible fluids, gas might accumulate in pockets or fill the entire system. When ice covered manholes become plugged such a gas might seep through the ground to find a pocket in a conduit where there was a short circuit and an explosion result.

3. A "burn-out" may have occurred in low powered cables forced to carry an overcharge. Such an overcharge would tend to break down the insulation containing oil soaked paper, thus forming a highly combustible gas.

In the opinion of an engineer of the Boston Sewer Department this last cause appears the most likely. The manholes involved had covers bolted to watertight frames beneath the usual loose-fitting surface covers. Grease was spread to prevent seepage of water into the conduit. Thus gas generated in the conduit would have little chance to escape by seepage at the manhole or other natural vents, and on ignition an explosion would seem inevitable.

Newburgh, N. Y., Sept. 16, 1929.*

One person was killed, about twenty-five were injured, and damage estimated at approximately $200,000 was done to property in a series of explosions which took place in the downtown business section of Newburgh along the Third Street sewer and its lateral connections.

The explosions occurred about 11:30 A.M. on September 16, 1929, and are believed to have been caused by the ignition of vapors from benzine, gasoline or illuminating gas which found its way into the sewer. All sewerage flows into the Hudson River, and it is thought that as a result of the outfall of the sewer being submerged the gases backed up and while so pent up were in some way ignited.

*Much of this data was extracted from an article which appeared in the March, 1930, issue of the *American City* magazine.

A feature of particular interest in connection with this occurrence is the fact that on August 24, 1928, a similar explosion took place in the same part of the city and along the same sewer. At that time there was no loss of life and property damage amounted to about $60,000. This 1928 explosion was attributed to the ignition from an unknown cause of an accumulation of gasoline or benzine vapor in the sewer. Certain recommendations were made to prevent future explosions and had been in part carried out.

In view of this previous occurrence and the recommendations made, it appeared, when this second disaster followed within thirteen months, that a thorough investigation was warranted. At the request of the City Manager, the Director of the Bureau of Mines assigned Mr. G. W. Jones, explosives chemist, to assist in the investigation of the possible causes of the explosions and recommend means for preventing a recurrence. At the same time the Central Hudson Gas and Electric Corporation asked the Independence Bureau of Philadelphia (Member N.F.P.A.) to make a similar report. From these reports much of the following data has been extracted.

Story of the Explosion.

A thorough examination of the sewer and territory adjacent to the area in which the explosions occurred made it quite certain that the explosions started somewhere above Third and Montgomery Streets and traveled downward along the Third Street sewer toward the Hudson River. At Third and Smith Streets the explosion was communicated to the Logan Robinson dry cleaning establishment. At Water and Third Streets it extended laterally north and south along Water Street to stores and buildings, and then continued down the Third Street sewer to the manhole at the railroad viaduct.

The evidence indicates that along Third Street only the manhole covers of the sewer were blown off. The one at Smith and Third Streets was estimated by one witness to have been hurled fifty feet, and it was broken into three pieces. The manhole cover at Third and Water Streets was blown off with less violence, while that at Third Street near the railroad viaduct was lifted only a few feet into the air. No manhole covers on the Water Street laterals were blown off, but the damage to buildings was most extensive along this street. A manhole cover of the Central Hudson Gas and Electric Company was blown off and broken in front of 70 Water Street, although there appears to have been no direct connection with the sewer system.

Damage to Buildings and Loss of Life.

On Smith Street the Logan Robinson building was damaged. Here the basement showed evidences of fire, which had charred somewhat a number of the splintered joists. On Water Street four buildings were considerably damaged, the most serious being those occupied by Green's bookstore and the Moe Myer ladies furnishings store. Minor explosions occurred in four other buildings, and external damage, largely to glass, was suffered by about twenty-five other structures.

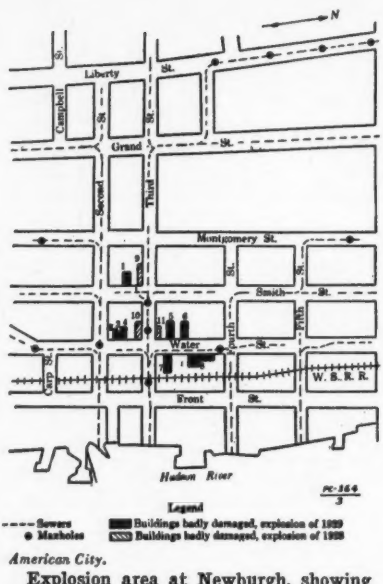
American City.

Store on the west side of Water Street, Newburgh, where the one fatality occurred.

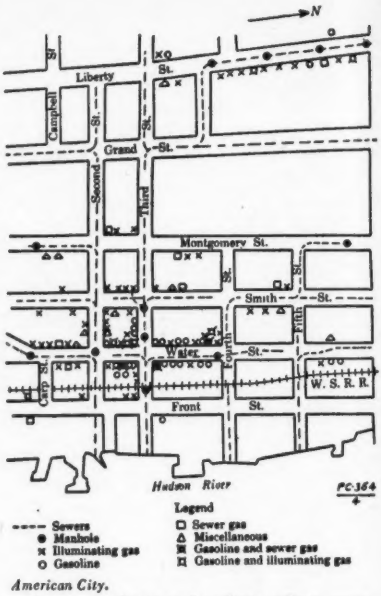
The loss of life occurred in the Greene bookstore following an internal explosion, which, according to newspaper reports, blew the proprietor through the doorway, across the sidewalk and against an automobile parked at the curb. His skull was fractured and he died in a hospital. The two floors of the building were crumpled and an employee was buried in the débris and seriously injured. Fire broke out but was promptly extinguished by the fire department.

In the Moe Myer store considerable fire resulted and lesser fires occurred in a number of other basements along Water Street. One department store building involved was equipped with automatic sprinklers which, however, were not a factor in extinguishing the small fire which started in the basement. The effect of the explosion in this building was confined to the ripping up of the wooden floor, small openings broken in the side walls and sheathing torn down from the ceiling. One sprinkler head was opened and a piece of $\frac{3}{4}$-inch pipe was broken off by the shock. No heads were opened by the fire which was started by flames from the sewer. It was extinguished by an employee with a soda-acid extinguisher. The loss in the building, largely to stock due to breakage and water, was estimated at $2400.

In view of the fact that in some of the stores wrecked by the explosion paper cardboard and light wooden boxes and cases of every description were thrown about and were ready to be ignited by a momentary flame of any kind, it seems remarkable that the resultant fires were not greater.



Explosion area at Newburgh, showing sewers, manholes and buildings seriously damaged.



Area at Newburgh where odors were reported in answer to questionnaire.

U. S. Bureau of Mines Investigation.

A questionnaire was prepared by Mr. Jones and delivered by the police and other municipal authorities to all business places and residences adjoining the Third Street sewer system. In reply to the question, "Have you been troubled with odors within the last three months?" 248 replied "no" and 111 replied "yes." The survey showed that more than 30 per cent of the business establishments and residences had been bothered with odors. The character of the odors reported is indicated by the diagram shown above.

The several possible sources of explosive gases were investigated by the Bureau of Mines experts, as follows:

Influence of Flammable Liquids.

No evidence was obtained to indicate that appreciable amounts of gasoline and similar flammable liquids had found their way into the Third Street sewer either before or after the explosion, other than in the replies to the questionnaire. Had gasoline been the major cause of the explosion, accumulations of concentrated vapor should have been present at the lower end of the Third Street sewer, and evidence shows that not to be the case.

Heavy oils and the like which might be washed into the sewer surely played no major part in these explosions. None of these have sufficient vapor pressures at the sewer temperatures observed during the investigations to produce an explosive mixture with air. Likewise, naphtha and kerosene liquids may be ruled out as the sole factor contributing to

these explosions, unless the sewer temperatures were higher on September 16 than found on later investigation.

Sewer Gas.

The Third Street sewer, which is of brick and approximately 3 feet in diameter from Montgomery Street to the river, passes down a steep grade to the river through the section in which the explosions occurred. The rate of sewage flow is much higher than in most sewer systems. The sewage, having a density equal to or greater than water, should be quickly carried out into the river before being appreciably attacked by bacteria or other agent. For this reason, there appears to be no possibility of true sewer gas having taken a major part in this explosion.

Illuminating Gas.

Tests made in Smith Street gave marked odors of illuminating gas. South of Third Street none in proportions sufficient to be detectable in the explosibility apparatus used was found. North of Third Street drill holes made about 20 feet from the corner showed gas coming from the ground. When lighted this gas would burn steadily for a minute or more.

A vault in the basement of the building at 48 Smith Street, which extends under the street beyond the curb line, and diagonally across from the Logan Robinson store, was investigated. Gas that was coming into this vault from the street was violently explosive, when tested in the explosibility apparatus. Explosive mixtures of gas and air were found to be coming into the vault on two successive nights.

As a result of these tests, gas pipes on Smith Street from Third to Second Street were uncovered and it was found that, to avoid running the main around the vault mentioned above, it had been raised and passed over the vault. It is reported that four leaks were found in this main, two very close to the vault where the explosive mixtures were detected.

Illuminating gas was detected in a Central Hudson Gas & Electric Co. manhole at Third and Grand Streets. Gas had leaked into this manhole in such quantities that the gas-air mixture in the manhole was almost explosive, as shown by the apparatus used. The gas mains were uncovered near the manhole mentioned, and it is reported that the 2-inch wrought iron main had entirely rusted through in one place. This main runs parallel to the Third Street sewer and rather close to it.

Possible Means of Ignition.

No definite information was obtainable by the Bureau of Mines as to how the explosive mixtures that caused the series of explosions were ignited. Possible sources of ignition are numerous, and the explosions may have been caused by one of the following means:

Direct Ignition.—By the dropping of a lighted cigarette, cigar or burning match through a manhole cover opening; by sparks or flames from the exhaust of an automobile passing over a manhole cover; by sparks caused by tools used by workmen in removing manhole covers or making repairs in the sewer; or by open flames taken into the sewer by workmen, under which are included open lights, gasoline torches and cigar lighters, etc.

Indirect Ignition.—Through sewer laterals leading to the basements of buildings or residences, or through openings leading to underground electric systems. Sources of ignition coming under this heading would include open flames, such as stoves, furnaces, boilers, hot water heaters, or gas jets; sparks from electrical equipment, such as switches, motors or other electrical devices; arcs due to the grounding or short-circuiting of electric light, power or telephone cables in street ducts or manholes.

Conclusion as to Cause.

A sufficient number of leaks of illuminating gas were found in the explosion area to account for the combustibles which were present in these explo-

sions, and it is the opinion of the experts of the United States Bureau of Mines that the evidence points largely to illuminating gas as the combustible substance that caused the explosions on September 16, 1929.

Recommendations of Bureau of Mines Report.

The U. S. Bureau of Mines experts recommended:

(1) The elimination of gas leaks;

(2) An ordinance to prohibit the disposal of combustible liquids in the sewer, and the provision of a place for the disposal of waste flammable liquids at a safe distance from the business district;

(3) That the sale of flammable liquids in small amounts to household users should be prohibited, inasmuch as these people are tempted to dispose of them by pouring them down the sewer;

(4) The stone drains in Newburgh should be replaced, as they have offered an easy path and pocket for escaping combustible gases and vapors;

(5) An examination of the Third Street sewer is necessary to determine whether the excessive inside pressure caused by the explosions has damaged the sewer to any extent;

(6) All sewer connections should be inspected to insure their tightness and to make certain that proper vents and traps have been provided in accordance with the plumbing code of the city of Newburgh;

(7) The entire Third Street sewer system, as well as all other sewer systems of Newburgh, should be amply ventilated;

(8) Complaints of odors anywhere in Newburgh should be investigated promptly to prevent the possibility of a recurrence of the explosive condition;

(9) The sewer should be inspected systematically at least once a month to ascertain whether combustible gases or vapors are accumulating;

(10) All basement walls and masonry partitions dividing properties and cellar floors should be made as gas-tight as possible by filling all cracks and openings with cement or other suitable material.

Independence Bureau Report.

The Independence Bureau (Member N.F.P.A.) reports the causes of the explosion as not due to illuminating gas, but rather to accumulations of gasoline vapor and other heavy gases. A summary of the more important features of this report follows.

Conclusions as to Cause.

a. The Third Street sewer was effectively sealed by the high tide.

b. Gasoline vapor and/or other heavy gases had accumulated in the Third Street sewer and its branches and were unable to escape, because the end of the sewer was sealed. This accumulation apparently took place over a reasonable period of time, judging from complaints received on the forenoon of the day of the explosions.

c. The mixture of vapors and air was ignited in a manner which it has not been possible to establish definitely.

d. The leaner mixture of gases in the upper part of the Third Street sewer exploded with violence, damaging the Smith Street manhole, cracking the sewer and apparently producing breaks in pavement between Smith and Water Streets. The Smith Street manhole cover was blown high into the air and broke into three pieces. Flame issued from the manhole but produced little smoke.

e. The heavier gasoline vapors, seeking the lower levels, produced a richer mixture. The manhole cover at Third and Water Streets was blown up, and from this yellow flame

American City.

Another section of Water Street, showing effects of explosion.

several times shot into the air and burned like a gasoline blow-torch. The manhole under the West Shore Railroad viaduct also blew off its cover and vented black smoke, which always follows incomplete combustion of a rich mixture of gasoline vapor.

f. From the branches leading into the main sewer, the fire spread into various basements through improper sewer connections or defective old stone drains or porous walls. Leakages from defective branch sewers may have seeped through the ground and penetrated old walls. Fire could conceivably follow such channels. The richer the mixture of gas, the slower the speed of travel of flame through a pipe or other passage. Under the conditions, perceptible time could be required for flame to reach and ignite vapors in basements, and this could account for the Moe Meyer explosion coming some time after the others.

g. In all cases where explosions occurred in buildings, it is a safe assumption that a vapor and air mixture had accumulated in basements or under the wooden floors which exist in the three buildings affected and that this mixture was ignited through the connections to the sewer system or through other openings in the basement walls.

h. The violence of the explosion in each building depended on the proportions of vapor and air (the explosive range of gasoline mixed with air is usually stated to be from 2 to 8 per cent), the amount of the mixture, the size of the basement, the structural features of the buildings, etc.

Why Gasoline Vapors are Believed Responsible.

A considerable number of establishments on the Third Street sewer system use substantial quantities of gasoline. There are, in addition, a large number of private dwellings where gasoline undoubtedly is used. Filling stations are located at various points on the

streets, sometimes close to catch basins. Admittedly there are plenty of possibilities of gasoline getting into the Third Street sewer.

The detailed and general opinion is almost unanimous that gasoline vapors were present in basements and on streets upon various occasions prior to the explosion, and especially was this true on the morning of September 16th. Twenty-six persons were interviewed, fourteen of whom were definite as to the odor of gasoline, and the rest were more or less uncertain. Gasoline was continually referred to in the meeting of September 17th when the Chamber of Commerce and Merchants Association met with the City Council and City Manager. The City Manager stated that gasoline odor was easily detected in the manhole under the West Shore viaduct at 2 A.M. on September 17th.

Opinions secured during the investigation of August, 1928, were to the same effect. Twelve out of fifteen property owners and tenants in the affected district were definite as to gasoline, two were uncertain as between sewer and illuminating gas, one had no opinion as to what the vapors were.

The order of the three definitely recorded manhole explosions, starting up the hill and working down, indicates a heavy gas, denser at the lower levels. The violence of the explosions also fits in with the gasoline theory. The Smith Street explosion was exceedingly sharp, the Water Street one not so strong, and the viaduct one more moderate still. The character of manhole flames and smoke also indicates a heavy gas. The flame at Smith Street was clear, at Water Street yellow, and dense smoke issued at the viaduct. Such smoke is characteristic of the burning of rich gasoline mixtures.

The complaints of gas odors generally, and especially prior to the last explosion, have come largely from the Water Street properties, indicating heavy vapors. It is conceivable that light gas could get into the Water Street sewer in large quantities, but once escaped into buildings it would have risen to upper levels. Illuminating gas is lighter than air; gasoline vapor, on the other hand, about three times as heavy as air.

The explosions in all cases definitely show that the explosive force was upwards from basements, indicating that vapor and air mixtures were there when ignited. The only possible exception to an absolutely definite statement to this effect might appear to be the Moe Meyer store, in which the last explosion occurred several minutes after the others. The glass front of this store had already been blown out. There apparently was a large shaft in the rear connecting the basement with the second story, and the blowing out of the second story windows, which occurred when a "dull thud" sounded in the Moe Meyer building, probably was due to gas pressure from the basement passing up this shaft. The basement mixture here was probably very rich, its ignition was slow, and its explosive force moderate.

An investigation of all complaints of gas received by the gas company between August 1st and September 16th shows the following:

Leak found at meter installation	13
Leak found to be in appliance or house piping	6
Leak found to be in service pipe	1
Odor of sewer gas found	1
No leak found	1
	22

Only one complaint was received from a property on the Third Street sewer system on Smith Street or below, and that was at No. 92 Water Street, where, on August 30th, a leak was reported, but sewer gas was detected. This building, incidentally, was not involved in the explosion.

The city executives stated that a number of complaints were received by them per-

sonally on the morning of the explosion, and gasoline odors were the general cause of these complaints.

Independence Bureau Recommendations.

The Independence Bureau made four recommendations to prevent the recurrence of explosions in the sewer system of Newburgh as follows:

a. Keep flammable liquids out of sewers.
b. Protect individual buildings against the sewer system.
c. Make the sewer system tight.
d. Arrange the sewers so that vapors cannot pocket at the lower end.

Other Manhole and Sewer Explosions.

JULY 23, 1917, NEW YORK CITY. An explosion occurred in West 23rd Street, at the river front, in which twelve manhole covers were blown into the air and a number of people injured. The explosion was near the wooden sewer which served as an outlet under a dock. This was found to be on fire, and had to be partially destroyed before the fire department could get control of the flames.

The garage of an express company was suspected of being one of the chief sources of the waste gasoline thought to have been the cause of this explosion. In addition to this occurrence, a number of workmen had been made ill by fumes while in these sewers.

DECEMBER 5, 1919, NEW YORK CITY. An explosion of gas occurred in underground conduits and vaults of power circuits in the neighborhood of Broadway and 31st Street. Manhole covers were blown on to roofs and through windows.

JANUARY 27, 1920, NEW YORK CITY. An explosion hurled a manhole cover and a large piece of asphalt into the air at Times Square. Soon afterward two manhole covers a short distance away were blown off. Car windows were broken, but no one was hurt.

FEBRUARY 17, 1921, NEW YORK CITY. A workman was opening a manhole at the corner of Broadway and Prince Street when an explosion of gas occurred in the hole. He was killed by a piece of cover striking his head.

APRIL 11, 1922, PITTSBURGH, PA. Workmen who had been installing an electric power service line were taking their tools from a manhole where they detected the odor of gas. One of them struck a match to locate the leak. The cover of another manhole some distance away was blown high into the air and descending passed through the windshield of an automobile. The driver was badly cut.

JULY 25, 1922, NEW YORK CITY. Gas in an electric conduit exploded with a roar, shattered the cover of a manhole and hurled bits of metal into a crowd. A baby was hit on the head and seriously injured, another person was struck and seven were burned. All were taken to hospitals. Repairmen found that a short circuit had caused the ignition of the gas.

MAY 13, 1923, NEW YORK CITY. An explosion on the East Side blew eight manhole covers into the air. An employee who was cleaning a conduit was injured.

NOVEMBER 12, 1925, WINCHESTER, MASS. Three members of a repair crew were seriously burned and a fourth so badly burned that he died, when escaping gas exploded in a manhole in which they were working.

The crew foreman was seated in a harness lowered well down into the hole resetting a gas valve. With no warning whatever an explosion occurred which could be heard a quarter of a mile away and was followed by a mass of flame which shot into the air.

While the flames, spreading as they issued from the small opening, were in full force, the three members of the crew reached into the flames, seized the ropes of the suspended seat and pulled the foreman from the hole. The foreman's clothes were all afire and he was so badly burned that he died next day in the hospital. The others were burned about the face, hands and arms.

JUNE 7, 1926, NEW YORK CITY. An explosion occurred in a sewer not far from Broadway and 125th Street. Manhole covers were blown into the air over a considerable area, automobile traffic was thrown into confusion, several machines being damaged, and pedestrians were thrown into a panic by the roar and flames which followed through the open manholes of the sewer. Several persons received minor injuries.

This explosion was variously attributed to illuminating gas, sewer gas, and gases from waste oil accumulations which became ignited in some way. Whether original surface floatings or oil stirred up from the bottom of the water in the sewer by the explosion, the fact remains that considerable quantities of burning oil passed down the sewer and out under the Daylight Pier on the Hudson River. The pier was set on fire and in spite of the vigorous efforts of the fire department the structure was badly damaged.

AUGUST 29, 1928, BOSTON, MASS. With an explosion that rocked the district, two manhole covers were blown into the air and plate glass was shattered in several stores shortly after two o'clock in the afternoon at Massachusetts Avenue and Boylston Street. Store and office windows were shattered and the streets were showered with falling glass. A second explosion, following the first by less than a minute, occurred within an arc lamp post, and the helmet-shaped metal cover of the lamp was hurled through the air. Six persons were injured by the flying glass, none seriously.

The only warning of the explosion was the flickering of lights in the stores. For a minute lights flickered on and off and then came the explosion, putting out all the lights. An automobile containing two persons was proceeding along Massachusetts Avenue, where the first manholes blew out. The car was directly over one cover, which struck the running board and fenders and ripped them off. The manhole cover was split in two and half of it shot into

the air. The car swerved to the side of the street but kept on going, and the driver sped out of the district with never a look behind.

After the first explosion traffic was again permitted, when, without warning, there came another explosion from a manhole from which the cover had been removed to allow fumes and smoke to escape. Clouds of green smoke and flame shot from the hole. Traffic was diverted and the fire department and electric light employees fought the blaze with foam and CO_2 equipment. There were a number of lesser explosions, but by 3:30 the district had quieted down and no fear was felt of further explosions.

This was the first time that CO_2 had been used on a fire in Boston, and reports indicate that it was a factor in extinguishing the fire and immediately cooled off the manholes so that workmen could make the necessary repairs on the cables.

The cause of the explosion was not definitely determined, but it was thought that a gas had formed in the manholes and conduits and was then ignited by a short circuit in the cables.

JANUARY 14, 1929, MILWAUKEE, WIS. City gas was used in a machine shop for heat-treating furnaces. This gas was compressed by two compressors in which water was used and the mixture thus obtained passed through a separator. Water from the separator was piped to a sewer manhole, and to this same manhole there was a drain (not trapped) from a pipe trench 3 feet square with cast iron covers in the heat treating building, in which were located two quenching-oil pipes.

For some time employees had smelled gas in this building and about a week previous had found a small leak in a gas pipe near a furnace. The leak was stopped, but the odor of gas still persisted. No further leaks were found, however. On Monday, Jan. 14, 1929, at 1:05 A.M., when the night shift was at work, a violent explosion occurred, blowing off about 100 feet of cast iron trench covers. Wire glass windows on the east and west sides of the building and in the sawtooth roof were cracked. Ten steel sashes were also badly damaged. The windows on the east side and roof were blown outward. Those on the west side were pulled in apparently from the vacuum following the explosion. A traveling conveyor was also thrown out of line. The flash burned one man severely and two others slightly.

A thorough examination made after the explosion disclosed a leak in one of the compressors. This allowed gas to escape to the sewer and then back up through the drain pipe to the pipe trench. An explosive mixture was formed and probably ignited by one of the burners at the furnace. Loss $1500.

MARCH 13, 1929, BOSTON, MASS. A short circuit in the cables in a manhole caused a slight explosion and blue flames broke through the paving and shot into the air for fifteen minutes on Cambridge Street. Smoke curled up from other manholes, but no explosion occurred.

JUNE 7, 1929, BOSTON, MASS. Two manhole explosions in close proximity, one on Sudbury Street and the other on Bowker Street, shortly after 8 o'clock in the evening, sent the covers flying into the air with roaring reports, but no injury or damage resulted.

Employees in a near-by power station were on the scene immediately and discovered the insulation of a cable was on fire, thereby creating a gas which had ignited and forced the covers.

OCTOBER 24, 1929, BOSTON, MASS. Two men were severely burned following an explosion in a sewer trench on River Street. The explosion occurred when one of the men struck a high tension cable with his pick, causing a spark which ignited sewer gas that had collected in the trench.

NOVEMBER 20, 1929, NEW YORK CITY. A short circuit of high tension wires in a manhole in front of 10 John Street threw the manhole cover a dozen feet into the air and spouted flames twenty feet high. The fire was quickly extinguished by the fire department and no material damage or injury resulted.

FEBRUARY 9, 1930, WORCESTER, MASS. A pedestrian was injured and narrowly escaped death when a cover of a gas system manhole on the Chander Street sidewalk blew up. Momentarily dazed, he started to run down the street away from the manhole when another cover about 100 feet away shot into the air.

FEBRUARY 25, 1930, BOSTON, MASS. Five manhole covers in Allen and Blossom Streets blew off shortly after nine o'clock in the morning, breaking glass in several houses and scattering pedestrians.

Twenty or more pedestrians were on the streets in the immediate vicinity, but none was injured. One of the covers was broken in two pieces and one section fell to the bottom of the manhole. A young woman asleep in her room was cut by flying glass when her window was broken.

Arriving in response to an alarm, firemen pulled the covers off other near-by manholes to prevent other possible explosions. According to the police, basing observations upon past experiences, the explosion might have been due to a combination of gases confined by plugged vent holes in the manhole covers.

New Orleans Wharf Fires.

Report by Louisiana Rating and Fire Prevention Bureau,
(Member N.F.P.A.).

Three wharf fires, two of them involving heavy losses, in a period of ten days early in March, focussed national attention upon the fire hazards of New Orleans' river front property. These fires bring out no new lessons; the fire hazard of the type of combustible construction employed in the New Orleans wharves has been all too well demonstrated by previous fires of a similar nature. The accompanying map shows the location of the serious wharf fires occurring over a period of years. Among these, QUARTERLY readers will remember particularly the fire of November 7, 1925, which caused a loss estimated at $4,000,000 (QUARTERLY, Vol. 19, No. 3, p. 247).

The three wharves involved in the recent fires, all under the control of the Board of Commissioners of the Port of New Orleans, are as follows:

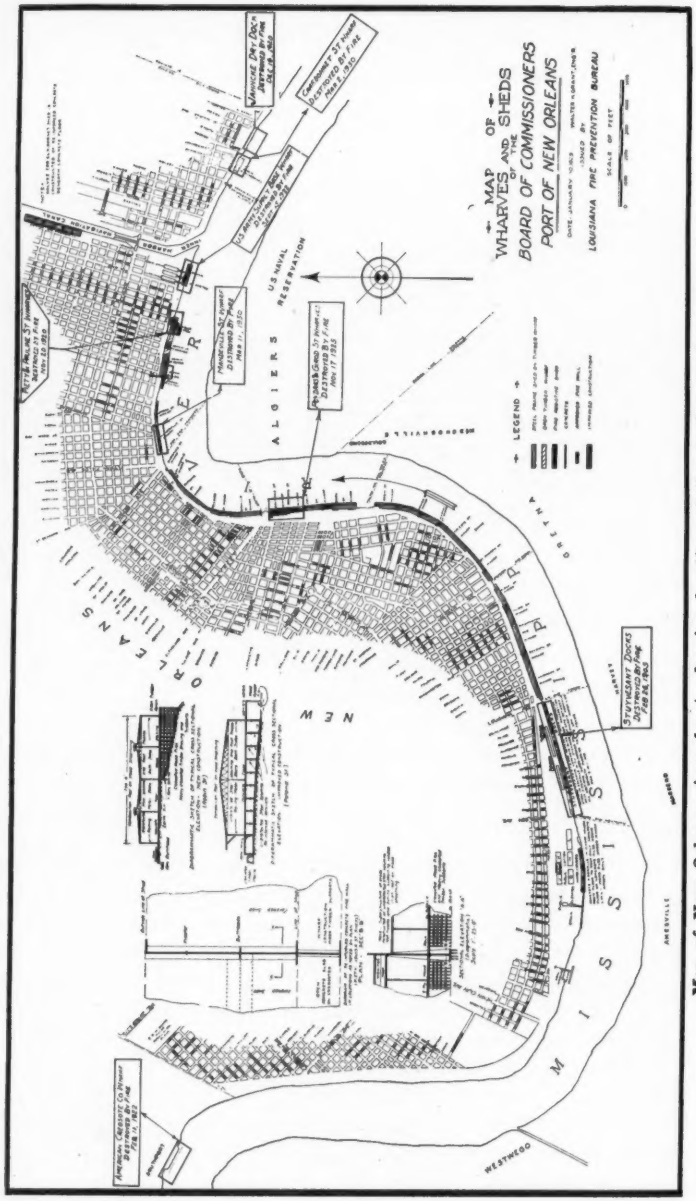
Wharf	Occupied as	Occupied by	Date of Fire
Charbonnet St.	Cotton Storage	New Orleans Compress Co. (Alabo Compress)	March 2, 1930
Mandeville St.	Miscellaneous freight, such as lumber, linseed oil, sugar, flour, coffee.	Various shipping companies	March 11, 1930
Public Storage Warehouse	Cotton Storage	Public Cotton Warehouse	March 12, 1930

The Charbonnet Street Wharf Fire.

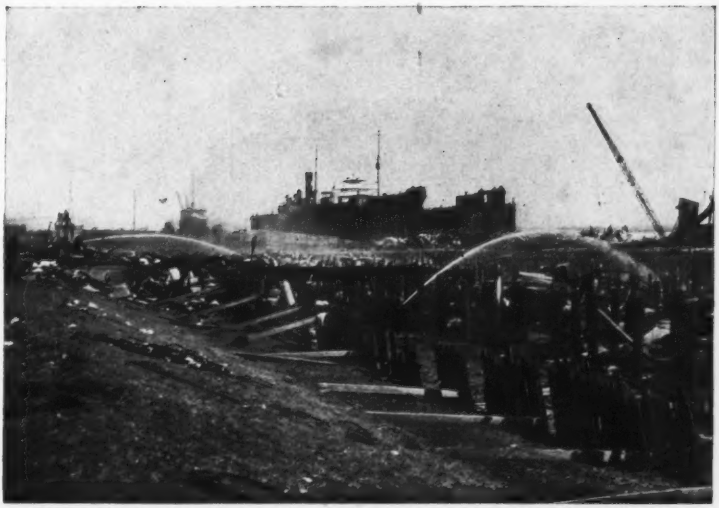
The Charbonnet Street wharf was located about four miles downstream from Canal Street. The building was frame, iron-clad, of the old type construction built on wharf of heavy wooden plank floor on creosoted wood beams and piling. The storage portion of the building covered an area of approximately 100,000 sq. ft. and extended 500 feet along the river front. The roof was of wood covered with metal. The side walls were enclosed in corrugated iron to within 7 feet of the floor.

Private protection consisted of standpipes and hose, two 40-gallon chemical engines and one watchman reporting hourly at night to two N. D. T. stations; also three watchmen who did not report to watch stations. Public protection consisted of four public hydrants within 500 feet, the New Orleans Fire Department and two fire boats belonging to the Board of Commissioners of the Port of New Orleans.

At the time of the fire 18,562 bales of cotton, principally high density compress, were stored on the wharf. Storage conditions were extremely congested, cotton being tiered throughout majority of the building.



Map of New Orleans river front, showing location of the various serious wharf fires.

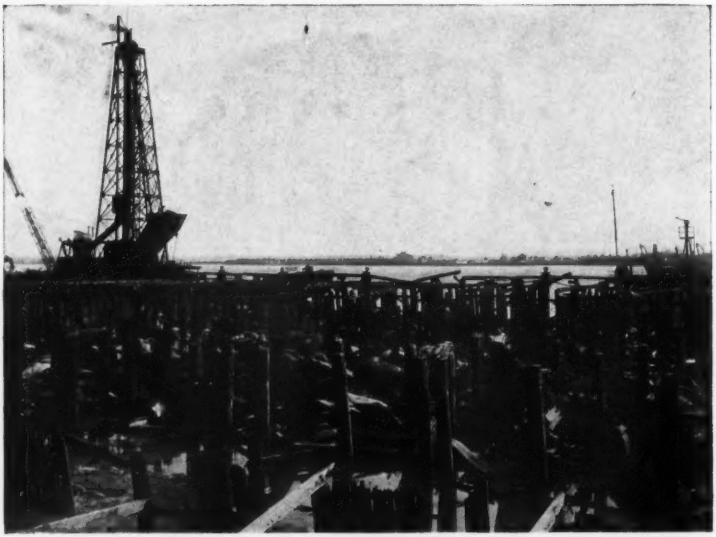


Ruins of the Charbonnet Street wharf. Downstream portion. This wharf extended more than 500 ft. along the river front, with no fire break.

This being essentially an unsprinklered frame cotton storage shed on a timber wharf, shed having partly open sides and containing 18,562 bales of cotton, any fire originating in this structure could be expected to be a total loss, as the entire building and contents was subject to one fire.

The Story of the Fire.

The fire was discovered at about 6:07 P.M., March 2, in the downstream end of the wharf, practically simultaneously by the dock board watchman and an Alabo Compress watchman. The alarm was turned in at 6:08 P.M., to which four pumpers and one ladder truck responded. So rapid was the spread of flames over the cotton that a second alarm was turned in at 6:13 P.M. By that time the entire wharf was ablaze and a general alarm was turned in shortly afterwards, bringing to the scene all available apparatus. The fire boat *Samson* was anchored in the fore bay of the Industrial Canal, about one-half mile from the fire and arrived at the scene about 6:20 P.M. The fire boat *Deluge,* stationed upstream from the fire a distance of approximately 5 miles, arrived at 6:30 P.M. The operations of both fire boats were delayed for a while until the steamship *Scantic,* which was docked at the wharf, could be towed out into the river. The intense heat and smoke of the fire, fanned by a stiff off-shore breeze, kept both fire boats beyond effective working distance of the wharf, and allowed the collapse of the wharf sub-structure and consequently the entire wharf and contents.



Ruins of the Charbonnet Street wharf. Upstream portion. Remnants of corrugated iron sheathing of the wharf shed, and bales of cotton, among the piling.

The fire department, finding it impossible to combat the fire raging beneath the wharf floor, confined its efforts to preventing the spread of the blaze into the compress and warehouse of the Alabo Compress, in which they were successful, and to the extinguishment of the cotton which continued to burn after the collapse of the wharf. The fire continued to burn for two days afterwards and several minor fires broke out among bales of salvaged cotton due to flying sparks.

Loss of Life.

Due to the extreme rapidity with which flames spread throughout the wharf, the crew and visitors aboard the steamship *Scantic* were unable to reach shore through the wharf, which was their only means of exit, and were forced with the alternative of either jumping into the river or chancing rescue from the ship. Three lives were lost due to burns or suffocation, and three men were drowned when they jumped from the boat to the river. Approximately eleven others received treatment at local hospitals for burns and exposure.

Property Loss.

The wharf structure and equipment, according to a statement of values filed with the Bureau, was valued at $253,346.88, and was a total loss. The loss on cotton stored on the wharf will approximate $1,250,000. Damage to the steamship *Scantic* is as yet undetermined, but it is understood to be severe. The Alabo Compress Warehouse suffered some damage, principally from water.

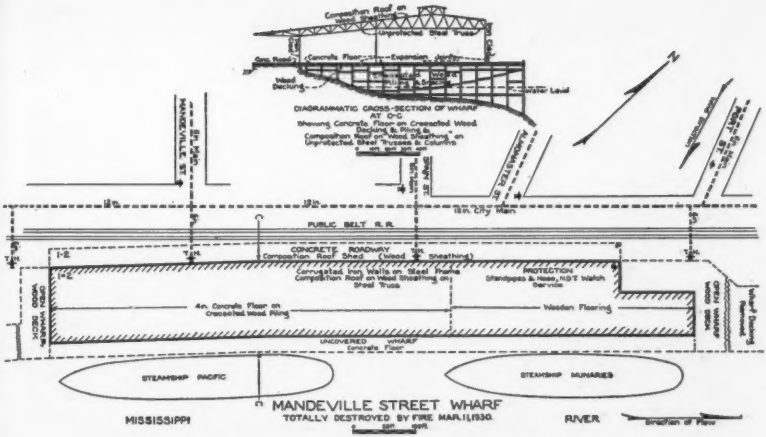


Diagram of Mandeville Street wharf, showing character of construction.

The Mandeville Street Wharf Fire.

The Mandeville Street wharf is located between Port and Marigny Streets, approximately one mile downstream from Canal Street.

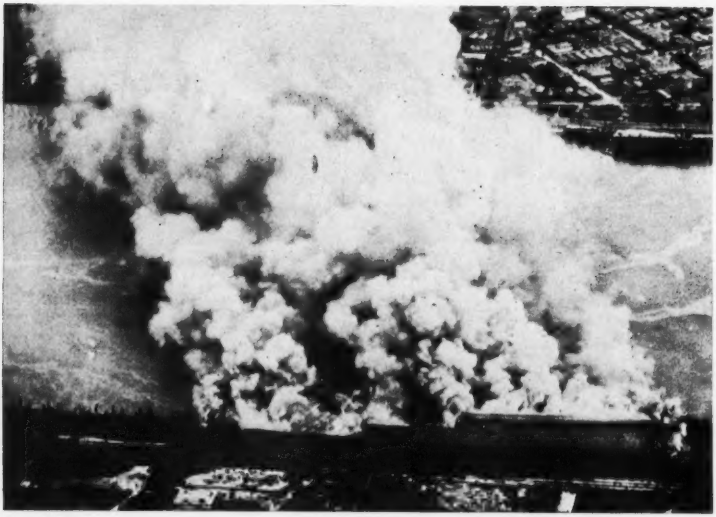
The wharf was of the usual type of construction, consisting of creosoted wood piling and heavy wood timbers. Approximately two-thirds of the floor area was covered with a 3-inch reinforced concrete slab placed direct on wood timbers. The remainder of the wharf floor was of heavy wood planking. No fire wall or draft stops were provided beneath wharf floor, thus forming one continuous fire area. The enclosed storage portion on the wharf was one high story, approximately 1050 feet long and 120 feet wide. Walls were of corrugated iron on unprotected steel frame. Roof was composition on wood sheathing on steel trusses.

Private protection consisted of standpipes and hose, and N. D. T. watch service, nights only. Public protection consisted of 13 public hydrants on 6 and 8-inch mains and fire department of City of New Orleans, as well as the fire boats *Samson* and *Deluge*.

The Story of the Fire.

The fire was discovered about 3:15 P.M., March 11, near the downstream end of the wharf by clerks of the Munson Line and dock policemen. An alarm was immediately transmitted to the fire department, who responded at once, and, upon arrival, sent in a general alarm which brought to the scene all available apparatus. The fire boats *Deluge* and *Samson* arrived shortly thereafter.

The fire, when discovered, seemed to be beneath the wharf and gained entrance into the storage portions above through the wood floor and the expansion joints in the concrete floor. The fire beneath the wharf spread with



International.

The Mandeville Street wharf fire from the air. The off-shore wind carried the fire to one of the two vessels at the wharf and handicapped the operations of the fire boats.

International.

The S.S. Munaires was moored at the Mandeville Street wharf at the time of the fire. The off-shore wind carried the fire to her cargo before the vessel could be moved from the wharf.

The Mandeville Street wharf, showing effect of heat on unprotected steel construction. The concrete deck collapsed when the combustible sub-structure was consumed.

amazing rapidity and enveloped the entire sub-structure within a few minutes. The fire among the cargo spread less rapidly, and had it not been for the failure of the wharf piling and consequent breaking of the concrete floor, the efforts of the fire department would have been sufficient to cope with the fire.

The presence of two steamships docked at the wharf again proved a detriment to operations of the fire boats, as the time required to move these boats from the wharf allowed the fire to spread to such an extent that it could not be coped with. An off-shore breeze aided firemen who worked from the land side, but proved a severe handicap to the fire boat operations.

The fire boats seemed to have been capably handled, in the face of great difficulties and danger; but their effectiveness against a fire well started under the present type of timber wharves was distinctly disappointing. The *Samson* especially, with its small capacity, seemed to be of little service.

The Mandeville Street shed was formerly connected to the Press Street shed below by an open frame wharf. At the time of the fire the Press Street shed had been removed, preparatory to rebuilding, and the wharf decking had been torn up. Otherwise the fire would have spread beneath the open wharf to the Press Street shed, and would also have destroyed this shed. The fire was stopped at the upper end by consuming all of the wharf and shed structure up to the open space for the Southern Pacific Railroad crossing.

Property Loss.

The entire wharf, with the exception of the concrete roadway beneath the land side shed, was a total loss. The value of this wharf as taken from the statement of values filed with this Bureau is $415,979.00. No exact figures were available on the value of the cargo stored therein, but it has been variously estimated at from $1,000,000 to $1,500,000. The steamship *Munaires* of the Munson Line, which was docked at the wharf adjacent to the point of origin of the fire, was severely damaged. This loss alone is expected to reach $500,000.

Remarks and Conclusions.

The Mandeville Street wharf shed was an unprotected steel building of excessive area on creosoted wooden piling, with wooden wharf deck covered for the most part by a concrete floor, and with wooden roof sheathing. The Louisiana Rating and Fire Prevention Bureau had repeatedly called attention to the hazard, as indicated by the following extracts from Bureau reports:

Prominently Undesirable Features—Owing to the rise and fall in river levels, the continuous wood pile and floor construction, the lack of fire walls and draft stops underneath, a fire fairly started and with favorable wind conditions would probably sweep to the end of the section involved. The fire-fighting force and facilities available would be powerless to cope with the chimney effect of such a fire.—*From Bureau report on Docks, Oct. 1, 1920.*

The Bureau offers no credit for concrete floors in combustible sub-structure.—*From Bureau letter to Louisiana Insurance Commission, May 8, 1929.*

That this fire, resulting in practically a total loss, was in accordance with the Bureau's predictions, is clearly shown by the following extracts from the New Orleans *Times-Picayune* of March 12, 1930:

A terrific draft swept the fire along, once it started in the creosoted piling underlying the concrete deck of the wharf. So great was the force derived from this flue-like effect that the tarry substance of the expansion joints, between concreted floor areas, was immediately burned away and the flames came up through the slits, igniting the cargo on the concrete floor. This underlying flame, however, vastly exceeded in speed the rate of travel of the fire within the wharf. Externally, the walls and roof, as well as the foundation of piling were enveloped in flame while much of the cargo still was unignited. This rapid spread prevented salvage.

* * * * *

Indicating the speed at which the fire spread through the piling, John McKay, general manager of the dock board, who reached the scene within 10 minutes of the outbreak, said that the flame followed as fast as he walked from the lower Port Street end to the upper end.

* * * * *

Reconstruction * * * was completed early in 1928. A feature of the reconstruction was the concrete wharf deck, which, however, did not prove any barrier to Tuesday's fire.

The non-combustible concrete floor laid over the wooden floor at this wharf performed entirely according to the predictions and expectations of fire protection engineers. It served as a horizontal retardant to the spread of the

The Mandeville Street wharf shed from the land side, upstream end, showing collapse of unprotected steel and cargo inside shed.

fire from the combustible piling and sub-structure to the building and contents above; but, unfortunately, did not prevent the ignition of the contents through the expansion joints, and also, unfortunately, did prevent any effective efforts toward extinguishing the fire beneath. From a very early period in the progress of the fire it was under control above the concrete deck, and from the start of the fire at 3:15 P.M., for three and one-half hours until the floor collapsed at 6:30 P.M., there seemed to be ample opportunity for salvaging the valuable contents of the dock warehouse, particularly in the upstream end. Apparently, however, it was considered dangerous to allow anyone to enter the building with the knowledge that the entire structure underneath the floors was being consumed, and no efforts towards salvaging seem to have been made.

Public Cotton Warehouse Fire.

The Public Cotton Warehouse is located near the Mississippi River, extending from Jena to Soniat Streets. The compress and warehouse buildings are all of fire-resistive construction; the warehouse portions are subdivided into separate compartments, each approximately 32 x 200 feet, with a lateral dwarf wall through the center.

All compartments were fully covered with a two-supply automatic sprinkler system as well as a standard system of outside hydrants and hose, and N. D. T. watch service. Doors to all compartments are kept closed except when compartment is being worked.

Story of the Fire.

The fire was discovered about 8:15 A.M. on March 12, in Compartment 17 of Unit H by a dock board watchman, who saw smoke pouring out from the compartment. An alarm was immediately transmitted to the fire department.

Several sprinkler heads in the compartment operated and held fire in check until it could be extinguished by hose streams.

The compartment contained at the time of the fire approximately 1200 bales of cotton. Of this number, 177 were damaged. The loss to the cotton is not expected to exceed $2500; only nominal damage to buildings.

The automatic sprinklers performed as in similar fires in the past and effectually checked the fire until extinguishment could be completed by hose streams.

General Recommendations.

We do not believe that a fire once fairly started in the creosoted piling and sub-structure commonly used along the New Orleans docks can be controlled by extinguishing facilities of the land fire department or the fire boats. We believe that, (1) the sub-structure should be entirely fire-resistive; (2) that existing combustible sub-structures should be subdivided by substantial fire walls and the progress of fires in these subdivided sections should be retarded by non-combustible draft stops; (3) that the only effective extinguishing agent would be a complete system of underfloor open sprinklers or "deluge" sprinkler systems, actuated by quick release valves and having a very plentiful water supply.

Hoboken Pier Fire.

A serious fire originating from hot ashes on a dump destroyed a concrete roadway built on wooden piling and part of two pier sheds of the Lamport and Holt Line at Hoboken, New Jersey, on the night of March 22, 1930. This fire is of particular interest in that it again indicates the hazards incidental to the highly flammable coating of bilge oil on the pilings and timbers beneath the wharf, and emphasizes the hazard of large unbroken areas under wooden wharves and piers beyond the reach of fire streams. The fire is also of interest in that it was successfully confined to the area under the concrete roadway for more than twelve hours, after which the roadway collapsed and permitted the fire to spread to the pier sheds.

The Property Involved.

The roadway involved in the fire consisted of a concrete slab 6 inches to 8 inches thick laid on a plank deck supported by wooden piles, leaving an open space of approximately three feet above the water level at high tide. The roadway led directly to the pier sheds on the main wharf. These pier sheds were approximately 980 feet long and of typical wharf construction, being of wood and corrugated iron on a steel frame. They were not equipped with automatic sprinklers.

Story of the Fire.

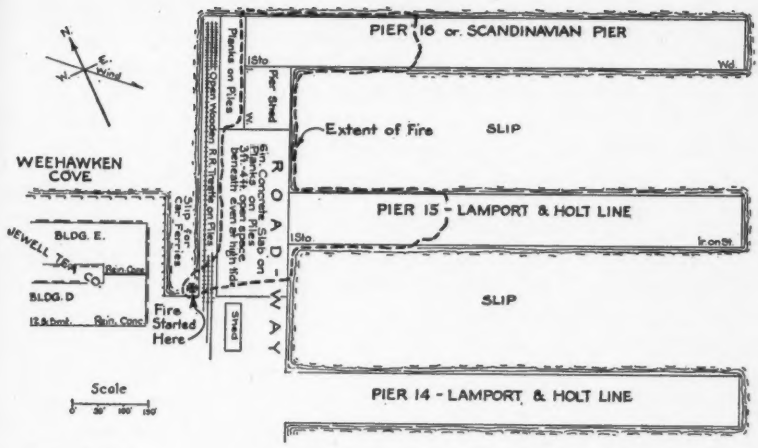
At 10:30 P.M., Saturday night, March 22, 1930, a policeman discovered a fire burning in a dump on the shore of the slip just back of the concrete roadway leading to the Lamport and Holt Line pier, and sent in a still alarm. When the fire department arrived the piles and timbers of the dock were burning, and a strong west wind was driving the fire under the wharf, which formed a roadway leading to the pier sheds. The fire department was quick to realize the magnitude of the job at hand. Fire boats were summoned at once from New York City, and apparatus and men were requested from Jersey City.

The piling and timbers in the concealed space under the roadway were covered with a black oily coating, due to the discharge of sludge from the fuel-oil tanks of boats. The flames spread rapidly over this oily deposit until the whole underside of the wharf was on fire. During the night the fire boats and land companies poured streams of water through holes chopped in the six-inch concrete flooring over the burning wooden underpinning, but with little apparent effect. The fire continued to burn fiercely. The firemen, using hydraulic rams and electric drills to make the holes, were menaced, not only by the thick smoke, but by the constant danger that the concrete plaza would collapse.

This report is largely based upon information furnished by C. W. Mowry (Member N.F.P.A.).

International.

An aerial view of the Hoboken Pier fire which engaged the fire fighters of three cities for more than twenty-four hours on March 22, 1930.



Factory Mutuals.

Diagram showing extent of fire.

Throughout Saturday night and Sunday morning the fire department did their best to keep the fire out of the pier sheds Nos. 15 and 16, and succeeded until Sunday noon, when the timber work under the concrete roadway was so badly burned that the roadway collapsed. The fire, continuing to burn fiercely under the collapsed roadway, finally ignited the shore ends of the unsprinklered pier sheds and extended down about one-third of their length before it was checked. A considerable amount of merchandise awaiting shipment was destroyed or damaged, and the loss to the roadway, piers and contents is estimated at between $500,000 and $1,000,000.

Adjoining the wharf and about 150 feet west is the twelve-story concrete building occupied by the Jewell Tea Company. Throughout the duration of the fire men were on duty at the plant ready to move material back from the windows should the wind shift and blow the heat toward the building. Due, however, to the favorable direction of the wind there was no damage to this building or its contents. Had the wind been from the east during the fire the wired glass windows would have prevented the entrance of flames from flying brands, but the susceptibility of the stock to smoke damage would have possibly occasioned some loss, and radiated heat might have opened some of the sprinklers inside, causing a water loss.

Two firemen were seriously injured. One, a member of the crew of the fireboat *James Duane,* was struck by the nozzle of a hose which in some way got out of control, and the other, a captain in the Jersey City department, was injured when he fell from the concrete roadway to the deck of a car float below.

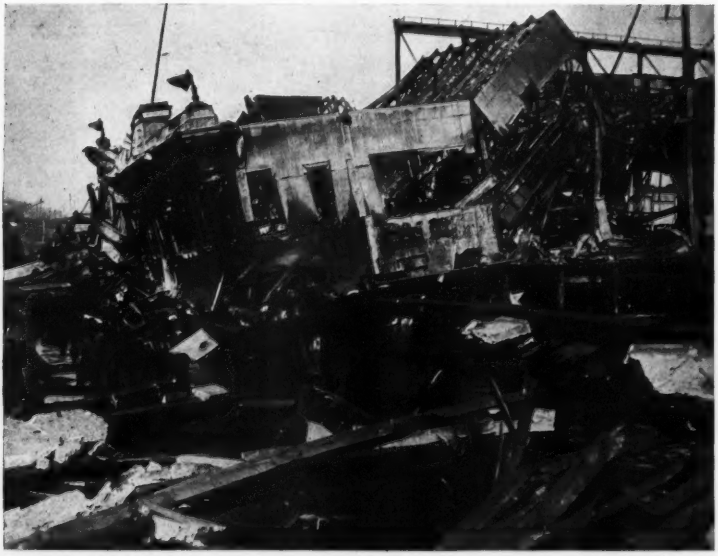
This is Hoboken's third major waterfront fire. The first was on June 30, 1900, when fire broke out on a pier warehouse of the North German Lloyd line, destroyed the pier and three liners, badly damaged a third, and caused a loss of 145 lives and a property damage amounting to $10,000,000. Most of those who lost their lives were trapped on the burning ships. The second fire destroyed the Clyde-Mallory line *Seneca* and two 700-foot piers on December 30, 1927. Property damage in this fire exceeded $1,250,000, but no lives were lost.

Conclusions.

This latest experience illustrates the fire hazard of large unbroken combustible areas under wooden wharves and piers beyond the reach of hose streams. It emphasizes the need of extending bulkheads under the pier deck downward to low tide level in order to effectively retard the spread of fire.

This fire is also indicative of the hazards of oily deposits on wood piling along the water front. This oil waste discharged from boats should be more safely disposed of, and legislation, if not already provided, should be enacted prohibiting such discharge while in harbors or at piers.

Automatic sprinklers in the pier sheds would have aided substantially in controlling the fire in these sheds. As in similar fires, their desirability in the space under the pier deck was demonstrated.



Underwood and Underwood.

Shore end of Lamport and Holt Pier 15, Hoboken, showing wreck of concrete roadway built on plank deck on wooden piles.

Airplane Hangar Fire Record.

The following record is to supplement the fire record of airplanes which was published in the last issue of the QUARTERLY (Volume 23, No. 3, page 258). Since the first of January, 1929, a special effort has been made to secure reports on all fires in the aviation field. Prior to this time, while fires in aviation properties had been occasionally reported to the N.F.P.A. Department of Fire Record, the number was relatively small.

It has been felt, however, that it was desirable to use fires which had occurred only during a recent period because of the rapidly changing character of the aviation industry. Accordingly the following record of forty fires covers eight fires in 1928, twenty-two in 1929, and ten in 1930 to date. Nine fires which occurred prior to January 1, 1928, have been omitted from the record for the reasons mentioned above.

It is very difficult in some cases to determine accurately from the records available the exact occupancy of the building involved in the fire. The N.F.P.A. record contains, for example, thirty-three fires in airplane manufacturing properties, eighteen of which were sprinklered. These fires have occurred over a period of several years. Care has been taken, however, to include in the present record only fires which are strictly hangar fires or which were at airports and partially used as hangars.

The reports come from a variety of sources. In some cases only newspaper stories have been available. In a considerable proportion, however, some

Wide World.

Photograph of a frame airplane storage building at Curtiss Field, Long Island, which was completely destroyed and a fire apparently set by a passer-by, who carelessly disposed of a cigarette. Stored airplane wings contributed to the rapid spread of fire.

satisfactory report from an inspection bureau, fire department or other reliable source has been obtained, so that it is felt that the records are reasonably accurate in all particulars referred to in the following. Considering the youth of the aviation industry, the number of large fires is surprising. Following is a list of the fires included in the N.F.P.A. files from 1928 to date.

Hangar Fires in N.F.P.A. Record.

Date	Place	Planes Destroyed	Reported Loss
	1928.		
Jan. 25	Bolling Field, Washington, D. C.	0	$500,000
March 27	Quincy, Ill.	1	12,000
July 3	Hoover Field, Washington, D. C.	8	60,000
July 29	Kelly Field, San Antonio, Texas	0	100,000
Oct. 11	Mitchel Field, L. I., N. Y.	0	250,000
Nov. 18	Vandalia, Ohio	4	45,000
Nov. 21	Keystone Field, Bristol, Pa.	1	75,000
Dec. 13	Airport, Oakland, Calif.	0	Small
	1929.		
Jan. 3	Airport, Boston, Mass.	1	2,500
Jan. 5	Post Field, Fort Sill, Okla.	3	200,000
Jan. 24	Fort Wayne, Ind.	0	Small
Jan. 29	Rickenbacker Airport, Stevens, S. D.	1	6,000
March 6	Stow Field, Akron, Ohio	8	50,000
March 13	Curtiss Field, Mineola, N. Y.	20	28,000
May 24	Airport, Rochester, N. Y.	1	20,000
May 30	Emmett, Idaho	2	15,000
June 11	Airport, Boston, Mass.	3	20,000
July 20	Sharon, Pa.	1	6,500
Aug. 5	Phoenix, Arizona	1	30,000
Aug. 6	Airport, Mansfield, Ohio	3	10,000
Aug. 21	Amsterdam, N. Y.	0	Considerable
Sept. 6	WIL Field, Granite City, Ill.	2	7,500
Sept. 11	Airport, Greenville, S. C.	1	4,000
Oct. 5	Airport, Ponca City, Okla.	2	20,000
Dec. 7	Love Field, Dallas, Tex.	0	8,000
Dec. 8	Love Field, Dallas, Tex.	12	110,000
Dec. 8	Scully Field, Detroit, Mich.	0	Moderate
Dec. 12	Airport, Tampa, Fla.	13	100,000
Dec. 22	Godfrey Airfield, Bangor, Me.	1	No data
Dec. 22	Fairbanks, Alaska	1	40,000
	1930.		
Jan. 4	Kellogg Airport, Battle Creek, Mich.	2	30,000
Jan. 13	Braley Flying School, Wichita, Kan.	11	70,000
Feb. 11	Naval Air Station, Washington, D. C.	0	500
Feb. 15	Capitol City Airport, Lansing, Mich.	9	100,000
March 4	Candler Field, Atlanta, Ga.	20	125,000
March 14	Selfridge Field, Mich.	0	Moderate
March 15	Hadley Field, South Plainfield, N. J.	14	200,000
March 18	New Wright Field, Dayton, O.	5	100,000
March 22	Airport, Newark, N. J.	2	40,000
March 24	Airport, Cleveland, O.	24	12,500

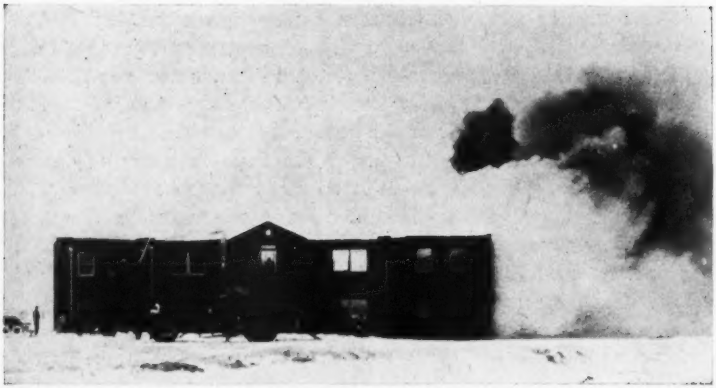
This record of forty fires includes a total of one hundred and fifty-four planes damaged or destroyed. This is an average of four per fire. The total loss in the thirty-four fires where a loss is given amounts to $2,400,000. This is an average of over $70,000 per fire, which is very high, even allowing for the fact that some of the reported losses may be high.

The reason for this record of fires is obvious. The occupancy is extra-hazardous, because of the ready combustibility of planes and the flammability of fuel, "dope," lacquers and paint which are in common use and frequently without proper safeguards, such as adequate ventilation and elimination of spark or flame-producing devices. Coupled to these high hazards, the occupancy is often housed in non-fire-resistive buildings of frame or unprotected steel construction, generally large in area so that large values are exposed to destruction in a single fire. When the fact that hangars are generally located at airports which are distant from water mains and public fire protection is added to the above conditions, the high losses are easily understandable. Other high hazard occupancies have taken advantage of automatic sprinkler protection, but comparatively few hangars have as yet been equipped with automatic sprinklers, and no fires in sprinklered hangars have been reported to the N.F.P.A. Department of Fire Record.

The causes of fires in these hangars are given in the following table.

Table of Fire Causes.

	No. of Fires	
Ignition of Flammable Vapors		13
Explosion, source unknown	4	
Doping operations	2	
Fires in engines	2	
Oil burner	1	
Washing plane with gasoline	1	
Flames from exhaust of engine	1	
Explosion of gas heater	1	
Ignition by blow torch	1	
Heating Appliances		5
Overheated furnace or stove	4	
Coal stove tipped over	1	
Smoking		4
Welding Operations		3
Welding gasoline tank	1	
Acetylene torch set fire to fabric of plane	1	
Acetylene torch ignited barrel of lacquer	1	
Miscellaneous		5
Supposed short circuit	2	
Fire in gasoline torch	1	
Lightning	1	
Children and matches	1	
Supposed Incendiary		2
Unknown		8
Total Fires		40



International.

The fire in the Braley School of Flying at Wichita, Kansas. The building was of mixed occupancy of ordinary brick joist construction with unprotected steel members in the portion devoted to the storage of airplanes. Nearly everything that could be wrong in the building from the fire standpoint was wrong here, hence the destruction of the building.

The common hazards of heating appliances, smoking and matches, as in most occupancies, are demonstrably important. The special hazards which have been reflected in fires are those of the flammable gasoline, doping and lacquer fumes, hazards of the gasoline engines themselves, and acetylene and other torches. There is no question from the above record but that special precautions to prevent the generation of flammable and explosive mixtures of various vapors and air must be taken.

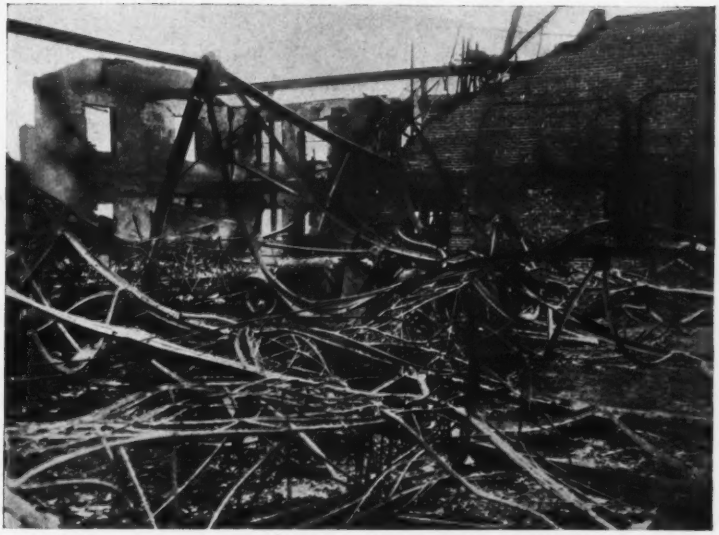
Detailed data as to what part of the building the fire started were in many cases not available. In about half the fires it was evident that the fire started in the main section of the hangar itself. In a few the fire started in adjoining machine and repair shops or miscellaneous other buildings adjacent. In three cases the hangars (frame construction) were set on fire from outside by grass fires or through a fire started by the careless disposal of a cigarette.

Following are brief reports of fires submitted as interesting, and typical of the hazards which must be protected in the hangar occupancy. They are arranged under various headings to indicate the general lesson of the several fires.

The Braley Flying School, Wichita, Kansas.

The fire which occurred on January 13, 1930, in the building occupied by the Braley School of Flying at Wichita, Kansas, illustrates a great many of the hazards which must be guarded against in hangar occupancies.

The building, which was occupied by offices, shop and hangar, was brick walled with wooden interior construction and a rear wall all of frame. The building had a heterogeneous occupancy, with various processes such as wood-



International.

The ruins of the school, shop and hangar building of the Braley School of Flying. The condition of the steel framework is typical of failure of steel, unprotected, to stand up in a fire. Automatic sprinklers could have held the fire to room where it originated.

working, doping, assembling and other details of the manufacture and repair of airplanes. The fire started in a small workroom. Six men, four of them students, were at work. The room was crowded, as the day was cold and all shop work connected with the school had been crowded into the one room. Men were hurrying to complete the refinishing of an airplane which had been promised for early delivery. The wings had been painted and were leaning against the wall of the room. As the lacquers and nitrate "dope" dry fast in a warm room, the workroom was being heated rapidly by a gas stove in an effort to bring the temperature up to approximately 110° F. to make possible the spraying of another coat of "dope" or lacquer on the wings.

Just as the desired temperature had been reached a flash fire occurred, apparently involving the entire room. Two of the occupants escaped through a window and four others dashed out the one door, two being slightly burned.

The flames spread rapidly, there being an accumulation of lacquer dust on benches and ledges. The fuselage and tail assembly, being covered with cotton fabric and coated at least five times with "dope" and lacquer, were immediately involved. So intense was the heat that the last man out of the door could not return near enough to close it. The two and one-half-gallon soda-acid extinguishers were of no value, the flames having spread so rapidly.

The Wichita fire department was called by telephone and sent three pieces of apparatus, one being a pumper which laid two lines of hose, taking suction from an adjacent pond. The entire hangar was involved and the roof had fallen before they arrived, so that their efforts were of little use. Flames had spread through unprotected openings in a brick wall to the shop and hangar, igniting the airplanes crowded therein. All planes used by the school were inside, as the weather did not permit flying.

Classes of the school in session on the second floor were being dismissed at the time of the fire. The men from these classes helped to save come furniture and fixtures. Some seven airplanes were saved and more might have been gotten out had not the large doors of the hangars been blocked by a large snowdrift.

The fire illustrates the hazard of flammable vapors and the folly of crowding repair operations. The hangar might not have been lost had the openings in the wall between the repair room and hangar been properly protected. Hand fire protection was useless and only the presence of a near-by pond made it possible for the fire department to do anything at all after their necessarily late arrival from a distance. Had automatic sprinklers been provided the loss would probably have been limited to the repair room alone. The total loss was approximately $70,000.

Repairing Operations.

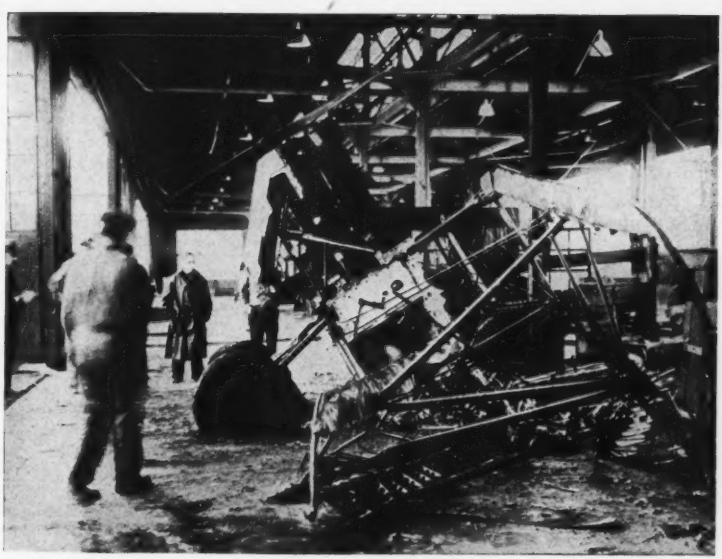
MARCH 27, 1928, QUINCY, ILL. Gasoline blow torch used to make repairs was accidentally tipped over by a mechanic. The fire destroyed the frame iron-clad hangar and one plane.

JANUARY 3, 1929, BOSTON, MASS. A biplane at the East Boston Airport was destroyed when an acetylene torch being used to weld a section of the tail structure ignited the fabric. In a few seconds the entire plane was afire, but prompt work on the part of attendants saved the wooden hangar which houses the repair shop. The plane was shoved out on the field and left to burn. Fire extinguishers were useless as the fire quickly involved the gasoline tank, which exploded.

JANUARY 24, 1929, FORT WAYNE, IND. Three men were injured when an airplane gasoline tank which they were welding exploded.

JULY 20, 1929, SHARON, PA. A workman using an acetylene torch ignited a barrel of lacquer and the resulting fire destroyed the one-story cement block building and three planes which were being repaired.

DECEMBER 22, 1929, BANGOR, MAINE. A machine which had been newly "doped" caught fire in an unknown manner as it was standing in front of its hangar. The Bangor fire department was called and was able to extinguish the fire in the plane, which was badly damaged, and prevented the spread of the fire to the hangar.



International.

The picture shows the ruins of an airplane under which two men were working when it suddenly caught fire in the engine. The two men underneath were drenched with gasoline and both died of burns. This fire occurred at the New Wright Field, Dayton, Ohio, and the fire was put out by the post fire department with assistance from Dayton. Five planes were destroyed.

JANUARY 3, 1930, BATTLE CREEK, MICH. A pilot was washing a plane with gasoline when fumes were ignited by an oil heater. The pilot was badly burned and the hangar and two planes were destroyed.

Lack of Protection.

JULY 3, 1928, WASHINGTON, D. C. Eight airplanes were destroyed in a fire of undetermined origin in the hangar of Hoover Field, Va. The blaze was discovered by a watchman, but the building was completely involved in the fire when the Washington fire department arrived. No mains or fire hydrants at the field were available and the firemen were forced to pump water from a river some distance away. The pumpers became mired in the process. The spread of the fire to adjacent buildings was largely prevented, however, by the fire department's work.

OCTOBER 11, 1928, VANDALIA, OHIO. This was a hangar with brick and glass walls with wooden roof on unprotected steel work. It contained eight planes, a gasoline tank truck, and was used for various other purposes. While water from hydrants was not available at the time of the fire because a water main had been broken the day before when it was run over by a heavy steam roller, there was, fortunately, a deep well on the premises which could be used.

A watchman discovered the fire when he was making his regular rounds. It spread so rapidly, however, that he made no attempt to use first aid extinguishers. The fire department responded and saved a near-by building.

MAY 23, 1929, ROCHESTER, N. Y. Gasoline fumes ignited by a blow torch used by mechanics in the workshop of the Rochester Airport caused an explosion which severely burned a man, destroyed an airplane and equipment, and also damaged an adjoining building. Fire fighters from Rochester were unable to help very much due to lack of water, although over a mile of hose and five pumpers were employed to get water to the fire. Two wheeled-type extinguishers and a number of smaller ones were used and they are reported to have helped check the spread of the fire. Plans for adequate water supply at the airport have been considered since the fire.

Building Construction.

JANUARY 26, 1928, BOLLING FIELD, WASHINGTON, D. C. A large sheet steel building was destroyed when an overheated furnace pipe in the operations office started a blaze which practically destroyed the warehouse and adjoining hangar and much flying equipment. The building was a common steel frame iron-clad structure and was practically ruined by the fire. Bolling Field has had several serious fires in addition to those which are included in this record. The Engineering Department was burned in January, 1926, and the Quartermaster's Section was destroyed in December, 1927. A newspaper clipping received as the QUARTERLY goes to press records another $30,000 hangar fire at this field on April 7, 1930.

MARCH 6, 1929, AKRON, OHIO. Eight airplanes in a wooden hangar were destroyed in the fire starting from an unknown cause. The hangar was also completely destroyed.

JUNE 11, 1929, BOSTON, MASS. Three airplanes, a motorcycle and supplies and equipment were destroyed in the hangar fire at the Boston Airport. The steel hangar is reported to have prevented the spread of flames, although structural members were seriously distorted and the building was probably injured beyond repair. The fire burned very rapidly, having started apparently from the ignition of gasoline fumes.

SEPTEMBER 11, 1929, GREENVILLE, S. C. A wood-frame and sheet-iron hangar was rapidly burned and one plane with it in a fire of unknown origin at the Greenville Airport.

AUGUST 6, 1929, MANSFIELD, OHIO. A frame sheet iron-clad hangar was destroyed with three planes.

MARCH 4, 1930, ATLANTA, GA. Twenty airplanes were destroyed in a wood frame metal-clad hangar at Candler Field, used for storing and repairing planes. When discovered, the fire had enveloped nearly half the building, having originated in a recently erected addition used for the storage of visiting

International.

Ruins of part of the building and one of the planes at Bolling Field, where a very serious loss was experienced in the destruction of a warehouse and hangar. This is an excellent demonstration of what happens to flimsy, unprotected metal construction in a fire.

planes. There was practically no protection, and little care with common hazards about the property had been exhibited.

Late Discovery.

DECEMBER 12, 1929, TAMPA, FLORIDA. Fire was discovered in the middle of the night by a neighbor in the all-metal hangar which contained thirteen airplanes, all of which were destroyed. Fire is thought to have been caused unintentionally by persons attempting to steal gasoline from the tanks of airplanes, which are estimated to have contained in all from 50 to 100 gallons. The fire department was able to do little to control the fire. Had there been a watchman there might not have been the considerable delay in discovering the fire.

FEBRUARY 15, 1930, LANSING, MICH. Fire destroyed the skeleton steel and fibreboard-sheathed hangar at the Capitol City Airport. The premises had been vacated early in the evening and fire was first noticed about midnight by a passing farmer, who tried at several near-by farmhouses before admittance could be gained to telephone to the city fire department. As there was no water supply at the airport no pumping engine was sent. By the time the fire department arrived the fire was beyond control, although a hangar 150 feet away was saved.

Wide World.

Ruins of hangar at Hoover Field, Va., which was destroyed by a quick burning fire. The wood roof burned off and unprotected steel members collapsed. (See also illustration on opposite page.)

How Fire Was Fought.

MARCH 23, 1930, NEWARK, N. J. This was a steel frame hangar with wooden roof on unprotected steel frame. It is the belief of the officer in charge of the hangar that the fire was set from without, as there was no one in the hangar at the time. The fire was first noticed on the wing of a monoplane adjacent to an open window, and at that time no more than three or four square feet of wing was involved. The alarm was immediately transmitted to the fire department by telephone. Three of the five ships were moved to safety. The door of the hangar was closed and an attempt made to fight the fire with 2½-gallon chemical extinguishers and a 33-gallon chemical engine.

However, due to the rapidity with which the fire started and the intense heat, it was not possible to use this equipment with any great success. The fire soon reached the gasoline tank of the ship. The arrival of the local fire department no doubt saved the building, as the intensity of the heat is shown by the buckling of upper chord of one steel truss. The roof of 2-inch plank, while charred, is probably still serviceable. Many windows were broken and two ships entirely destroyed.

Other Interesting Fires.

NOVEMBER 18, 1928, MITCHEL FIELD, LONG ISLAND. The engineering and experimental building, which seriously exposed a number of hangars, was destroyed in a fire which started supposedly from a short circuit and rapidly spread to the flammable plane structures until gasoline storage tanks and air-

U. S. Bureau of Standards.

Wreckage in the Hoover Field hangar, showing effects of heat. (See illustration on opposite page.) Left: Tips of duralumin propeller melted. Right: Bulged gasoline barrel.

planes were ignited. Buildings containing much valuable equipment, especially records of more than three years of research work, were destroyed. These are practically irreplaceable and represent a value reported to be in excess of $250,000.

DECEMBER 7 AND 8, 1929, LOVE FIELD, DALLAS, TEX. Two fires occurred from practically the same cause within two days. A person carelessly disposed of a match, starting a grass fire which spread and involved the frame buildings before it could be brought under control. The rules against smoking inside the hangars had apparently been rigidly enforced and it had been the practice of workmen to smoke outside and throw matches and cigarettes away near the building before coming back to work.

MARCH 15, 1930, HADLEY FIELD, SOUTH PLAINFIELD, N. J. The hangar was a one-story brick wood-joist building. There seems to be no doubt but that a fuel oil burner in a hot air heating system taking air from within a boiler room caused the explosion. The boiler room was cut off from the main building. It is believed, however, that due to some trouble with the fuel oil system, oil vapors filled the boiler room and were distributed throughout the building through the hot air ducts. At some point a proper mixture with the air existed and was probably ignited by the heater. The explosion spread the fire very rapidly.

There was no attempt made to use private equipment, due to the explosion. The volunteer fire department used three hose streams, which exhausted the available water supply in about ten minutes. The building, however, was practically destroyed by the time the fire department arrived.

Brockton City Home Fire.

Five persons lost their lives and a number of others barely escaped death by suffocation or burning when a fire swept through the main dormitory building of the Brockton, Massachusetts, City Home shortly after midnight on February 11, 1930. Inadequate private fire protection, lack of proper fire stops and frame construction were factors in the rapid spread of the flames upward from the basement, where the fire originated.

Buildings and Occupancy.

The Brockton City Home is situated on a hill at the head of Thatcher Street. The property consists of two main buildings and additions, together with several barns and other farm structures. The old or main building is of frame construction throughout with a roof of asbestos shingles. No firestops are provided and a vertical shaft or laundry chute extends from the basement to the attic. The center section of the main building is three stories in height

Frank Colby, Boston Transcript.

Lack of proper fire stops and frame construction were factors in the rapid spread of flames from the basement to the attic at the Brockton City Home fire, February 11, 1930.

This report has been prepared from data furnished by Chief Frank Dickinson (member N.F.P.A.) of the Brockton Fire Department and by members of the staff of the City Home, eyewitnesses, and other sources.

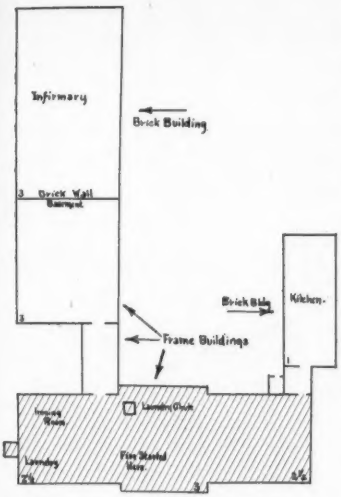


Diagram of Brockton City Home.
(Fire area indicated by shading.)

with a mansard roof. On either side of the central section is a wing two and a half stories in height having a sloping roof with dormer windows.

Connected with the main building by a two-story frame passageway is the newer infirmary building, part frame and part brick. The construction of the frame portion is similar to the older main building, but the brick portion is of modern brick and joist construction. In the basement a solid brick wall separates the brick section from the frame.

The main building was used as an administration building and dormitory. A laundry, bread mixing room and storerooms occupied the basement. Offices and service rooms occupied the first floor. On the second floor were rooms for the staff and some of the inmates, while in the attic were rooms for some of the help and a dormitory for thirty old men.

The new building has a dining room for inmates in the basement, a chapel on the second floor, and the remainder of the building is used for infirmary purposes. The kitchen and heating plant are located in a one-story brick addition erected at the northeast corner of the main building.

Fire Protection and Exit Facilities.

Public fire protection was provided by the city fire department and the city water works. The former has a station located about 1¼ miles from the Home, of which distance the last half mile is over a very rough dirt road.

An eight-inch water main comes part way out Thatcher Street, but from a point about ¾ mile from the Home it becomes a six-inch main, ending in a "dead-end" about 300 feet beyond the entrance to the Home. Three hydrants on this main are available, one in front of the entrance to the Home, one about 300 feet nearer the city, and one at the "dead-end."

A city fire alarm box was provided *inside* the main building, so located as to be difficult of access in an emergency. It was on the outside wall of the room used as an office, and when the door of the room was opened it was partly concealed. The telephone was in the same room.

A standpipe was located in the corridor of the central portion of the main building with hose and nozzle on each floor. From the general condition of

the hose after the fire it seems evident that no attempt was made to use this equipment on any floor. On the third floor the hose was burned as it lay coiled on the rack.

At least one 2½-gallon and one 5-gallon soda-acid extinguisher were provided in the laundry. Both of these were found after the fire properly charged and ready to operate, but with the hose burned off. Another 2½-gallon soda-acid extinguisher was in the kitchen. Both the main building and the infirmary were equipped with carbon tetrachloride glass bulb extinguishers, there being some 114 of these distributed about the buildings.

Metal-clad fire doors separated the passageway to the infirmary from the main building, but they were set in combustible partitions. These doors were apparently effective in holding the fire at this point from entering the passageway by means of draft or heat radiation, but the fire did enter to some extent through the partitions. Such fire as occurred at this point was effectively stopped by the efforts of the fire department.

The exit facilities from the upper floors of the main building consisted of a front and rear stairway from the second to the first floor and two stairways from the attic to the second floor. It seems probable that these stairs were used by those who escaped from the building, other than those who were taken down ladders by firemen. Fire escapes were provided at each end of the building, but they were not used as a means of escape.

Story of the Fire.

The fire was discovered shortly after 12:30 in the morning by the cook, who occupied a room on the third floor. Awakened by the smell of smoke, she descended to the kitchen to investigate and saw smoke issuing from the front part of the basement.

Retracing her steps, she returned to the third floor and aroused two colored maids who occupied rooms adjoining her own. Attired only in their night clothes the trio made their way out of the building, which by this time was rapidly filling with smoke, shouting a warning as they passed along the corridors.

About this time the night nurse in the women's infirmary also smelled smoke and started to investigate. As she proceeded through the passageway which joins the infirmary with the main building, she noticed flames issuing from the windows of the laundry, which is located in the basement.

Sensing the seriousness of the situation, she called the orderly in charge of the men's infirmary and the matron of the infirmary. Together they started out to awaken the sleeping inmates. They went from door to door, pounding and shouting warnings, urging all to flee for their lives. The majority of men and women had been awakened by this time and were preparing to leave the building.

Frank Colby, Boston Transcript.

The chief avenue of escape from the upper floors of the Brockton City Home was by means of these stairs, while fire roared through the adjacent hollow partitions.

After warning the inmates on the second and third floors and receiving their assurances that they were awake and ready to leave, the matron groped her way to the office on the first floor, on the outside wall of which was located a city fire alarm box. She reached the office but was unable to sound the alarm, due to the heat and smoke which filled the room. This room was directly over the section where the fire started and naturally would be one of the first places to become untenable. The telephone was also useless due to the wires having been burned off. She then made her escape with some difficulty. The orderly was dispatched to the nearest neighbor and an old man inmate was sent to sound an alarm from the nearest fire alarm box, both about half a mile away. Both calls were received by fire alarm headquarters almost simultaneously. On the arrival of the fire department additional alarms summoned the entire department to the scene.

The first engine company to arrive connected to the hydrant at the entrance to the Home. Farther along Thatcher Street a second engine was placed and two lines laid, while a third engine was located on Thatcher Street almost a mile away. Water pressures were inadequate, and use was made of the chemical tanks with which all the companies were equipped.

By the time the firemen arrived most of the inmates were out, but two remained to be rescued by the firemen and three perished in the flames. The

Frank Colby, Boston Transcript.

Complete destruction of top floor of Brockton City Home main building. Thirty old men had their quarters on this floor. Note exit to fire escape in background.

first to be rescued was a woman weighing well over 200 pounds. Although conscious, she was unable to talk and was on the verge of collapse when discovered in her room on the second floor. She had suffered considerably from smoke and had fallen on the floor as she attempted to make her escape. She was rescued by means of ladders with difficulty, and was rushed to a hospital, where she subsequently died.

Shortly after this rescue the firemen were notified that an old man occupying a room in the west wing of the attic with several others had not been accounted for. Ladders were raised to the windows and a search made without success. A short time later, as firemen made their way upward through the building, they found the unconscious form of this man huddled in the stairway leading to the third floor. He, too, was rushed to the hospital, where he died a few days later.

Of the three victims who instantly lost their lives in the fire, one was on the second floor and two on the third. The one on the second floor was a woman who occupied a front room almost over the place of origin of the fire in the basement. She evidently was at the point of suffocation from smoke

when she awoke. Circumstances seem to indicate that after leaving her bed she fell to the floor, where she remained until later found.

The other two victims were old men who had been overcome and then burned on the third floor. One was found under a mattress which had been dragged from a bed.

The cause of the fire has not been definitely determined. Evidence seems to point to the fact that the fire originated in a room at the front of the basement in which was located the bread mixing machinery. A short circuit or defective wiring was blamed for the blaze, and this seems a reasonable deduction.

The fire spread to the upper portions of the building by means of partitions and the laundry chute. The flames mushroomed in the attic and, held in by the roof, completely gutted the entire top floor. It was here that the greatest damage was done. The property loss is estimated at $50,000.

An automatic sprinkler system in the basement would probably have extinguished the fire at the start or at least controlled it until the arrival of the fire department. Neither the carbon tetrachloride glass bulb extinguishers which were distributed throughout the building nor the standpipe and hose were factors in preventing the spread of the flames and consequent loss of life. The former proved too limited in range of action to have any appreciable effect, while the latter would have required a trained force to use it effectively.

Frank Colby, Boston Transcript.

Here were found the bodies of two old men in the attic of the Brockton City Home. One was huddled under the charred remains of his mattress.

Gunther Building Fire, Chicago.

Report by George P. Stahl,
Chicago Board of Underwriters (Member N.F.P.A.).

On February 10, 1930, a fire occurred in Chicago which was marked by two remarkable and spectacular feats of life-saving. Shortly after the fire started, two men and one woman jumped from the eighth floor to life nets. This is probably the highest successful jump ever made. Immediately after this four women and two men were rescued from the eighth floor by means of scaling ladders.

Description of Building.

The Gunther Building is located at 1018-24 S. Wabash Avenue, on the northwest corner of South Wabash Avenue and East 11th Street. It is an eight-story and basement building of fire-resistive construction, 80 by 115 feet. Floor space is divided by hollow tile partitions. The major floor openings consist of one stairway, basement to roof, with self-closing metal doors at landings; and one stairway, first to eighth floor, open at landings. Elevators consist of one in hollow tile enclosure, basement to eighth floor, with doors closed by operator; and one, in bank of two from basement to eighth floor in hollow tile enclosure, with wired glass paneled iron doors in halls of hollow tile and thin glass windows. These afforded the means of egress, together with an outside fire escape on the southwest corner of the building.

The building was occupied by various tenants, principally office and mercantile, with some light manufacturing. The portion of the seventh floor where the fire originated was occupied by Thompson and Thorne Company, manufacturing silk pillows and pillow covers. Their occupancy consisted of power sewing machines, stock of pillows, covers, silks, piece goods, and bales of cotton pillow fillings. Another concern occupied the front portion of the seventh floor as an office. The eighth floor was occupied in part by Bland Brothers, film distributors. It was from these premises the people jumped to the life nets and those who remained were rescued by means of pompier or scaling ladders.

Fire Protection.

The principal fire protection within the building consists of a four-inch standpipe from the basement up, located at about the center of the building. Hose outlets are provided at each floor and are equipped with 100 feet of 2½-inch unlined linen hose with nozzle attached. Water supply consists of a 2500-gallon house tank maintained full by an automatic pump. A siamese connection is also provided for fire department use.

Story of the Fire.

The fire occurred February 10th, 1930, at 4:36 P.M. It started in the premises of the Thompson and Thorne Company, who occupied a portion of the seventh floor for the manufacture of silk pillows. Sparks from an electric motor igniting cotton pillow fillings, was given as the cause. The cotton burned rapidly, giving off intense heat and smoke. The actual fire involved an area of only about 60 by 80 feet, but the smoke and heat soon filled the seventh floor and extended to the eighth floor by means of the open stairs near the front of the building.

There were quite a number of people on the seventh and eighth floors when the fire started, and most of them got out safely. The people on the eighth floor were warned to leave the building without delay and the two front elevators were kept in operation until the operators could stay no longer at their posts. However, in spite of the timely warning and the efforts of the elevator operators, nine persons were trapped in the front part of the eighth floor. Their means of escape were cut off by heat and smoke that extended to this floor through the open stairs. These people were protected to some extent, temporarily, by hollow tile partitions between them and the open stairs. One man on the seventh floor, who had been out of the building once, returned to see that all others were out. He was unable to regain the front stairs and remained on this floor until the fire was out. Hollow tile partitions prevented the fire from reaching him.

International.

Wabash Avenue front of the Gunther Building. Three persons jumped to life nets from the top floor when cut off by fire starting on the floor below them. Note ladder to sixth floor. Scaling ladders were used above this point.

The first notification of the fire was received at 4:36 P.M. over the telephone by Engine Company 21, located a short distance from the fire. At 4:39 P.M. a box alarm was sounded, followed by a second and third alarm, bringing considerable apparatus and three fire department ambulances to the scene. Two additional truck companies were called because when the second man landed in the net the locking device of the net was broken, and service-

able nets were necessary in the event of more jumping. These additional nets were spread and held in readiness, but were not used.

Upon the arrival of the fire department, smoke was coming out of the windows on the seventh floor. People were at the windows of the sixth floor, but as they did not appear to be excited they were not considered in any immediate danger. A number of people were also seen at the windows on the eighth floor. There was not much smoke around these people and it was thought that the firemen inside would be able to reach them without difficulty.

An engine company, under the direction of a battalion chief, proceeded to the sixth floor to connect to the inside standpipe at this point, the engine supplying water to the standpipe through the siamese connection. Other fire companies arriving were ordered to the seventh floor, bringing hose up the front stairway, and a truck company was ordered up the fire escape to ventilate.

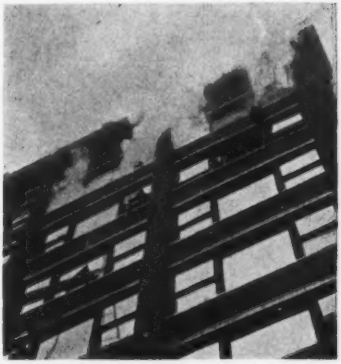
About this time a man climbed out of a window on the eighth floor and was hanging over the sidewalk from the sill. Orders were given to spread life nets under this window. This was done, and with firemen, insurance patrolmen and civilians holding the nets, two men and a woman jumped a distance of about 90 feet. They landed in the nets fairly well, considering the height of the jump.

The first to jump was a man. He leaped clear of the building and landed in the net without any serious injuries. The other man did about the same, excepting that he was slightly injured. The woman, however, fell straight down, rather close to the building. She was severely jarred when she struck the net. The force of her landing caused her to hit the sidewalk after the fall had been broken by the net. She sustained severe injuries. One civilian, who assisted in holding the life net, had his collar bone fractured when the girl landed in the net. He had attempted to support the net on his shoulder.

Just as the first nets were spread, the battalion chief in charge of the companies operating within the building reported that he was unable to reach the eighth floor by means of the stairway because of heat and smoke. Accordingly a truck company was ordered to raise an 85-foot aerial ladder for the assistance of the people still stranded on the eighth floor. Parked automobiles interfered with placing the ladder truck close to the building, so this ladder reached only to the windows of the sixth floor.

Scaling ladders were then brought into use and placed to the windows of the eighth floor, where six persons still remained. Four women and two men descended these ladders to the seventh floor, from whence they were assisted to safety. After this, firemen climbed to the eighth floor by means of the scaling ladders and ascertained there were no more people there. Ropes were also sent to the roof and lowered to the eighth floor. They were not used, however, as all the endangered occupants had been rescued.

Chicago Daily News.
Man jumping from eighth story window.



Chicago Daily News.
Using scaling ladders between seventh and eighth floors.

The main body of the fire, at the center of the seventh floor, was quickly extinguished after ventilation was effected, but on account of not being able to reach the eighth floor by means of the front stair shaft with hose streams, a water tower was placed in operation on the 11th Street side of the building. A heavy stream from this tower, supplied by four engines, was played in through the windows for a few seconds to cool the fire. The loss to contents on the seventh floor was considerable; damage to the building consisted largely of broken windows, and scored walls, ceilings and flooring of the seventh and eighth floors.

Conclusions.

The spectacular rescues at this fire demonstrate the value of life nets and scaling ladders when used by a competent department for emergency rescue work. In this instance the rescue work was necessary immediately after the arrival of the fire department, and the nets and scaling ladders, under the existing conditions, furnished the only means of escape for the endangered occupants. If all stairs and elevators had been enclosed the spread of smoke, heat and fire to the eighth floor would have been prevented, or at least very materially delayed, and a safe means of egress provided for the occupants of all floors.

Hotel Marguery Fire.

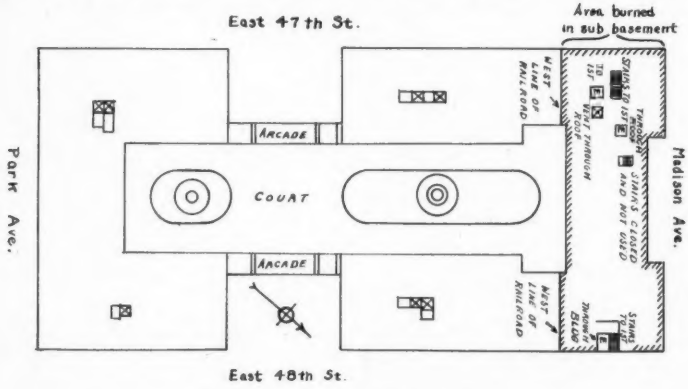
The Hotel Marguery, a New York apartment hotel of fire-resistive construction, was damaged by fire to the extent of $300,000 on January 3, 1930, when fire started in a sub-basement. Two lives were lost, and the occupants of the apartments were driven to the streets. The loss was due primarily to highly flammable contents located below the street level, without proper fire protection, with imperfect cut-off between the fire area and the floors above, making a fire very difficult for the fire department to handle.

Construction and Occupancy.

The building involved is about 33,000 square feet in area and occupies the block bounded by Park Avenue, 47th Street, Madison Avenue and 48th Street. It is of fire-resistive steel skeleton construction, having twelve stories, a basement and three sub-basements. Approximately forty per cent of the plot on which the building is erected includes two levels of the tunnel tracks of the New York Central Railroad.

The first floor, basement, sub-basement and second sub-basement are occupied by various mercantile stores with sales and storage rooms. A restaurant occupied the first floor on the Park Avenue Side. The third sub-basement is used for pump and ventilating rooms and storerooms for tenants. The second to twelfth floors are occupied for apartments.

Among the mercantile tenants was the Thonet-Wanner Co., Inc. who occupied approximately 600 square feet of space on the street floor, 2400 square feet for open display of furniture in the basement, and 20,000 square feet for the same purpose in both the first sub-basement and the second sub-



Ground plan of the Hotel Marguery.

basement. Part of the space in the second sub-basement was given over to the firm's offices.

Fire Protection.

Fire protection consisted of a night watchman making three rounds to twenty-three stations and seven 4-in. standpipes, four in the Madison Ave. section of the building and three in the Park Avenue section. Outlets were provided with 1½-in. hose attached on all floors and in basements. Standpipes were supplied from house tanks on the roof, which in turn were supplied by three electric driven house pumps taking suction from 15,000 gallon suction tanks in the third sub-basement. Outside pumper connections were also provided.

Automatic sprinklers were installed in a small part of the basement and first and second sub-basements in the Madison Avenue section, supplied by outside pumper connection only. These sprinklers were not a factor in the extinguishment of the fire.

Origin and Spread of Fire.

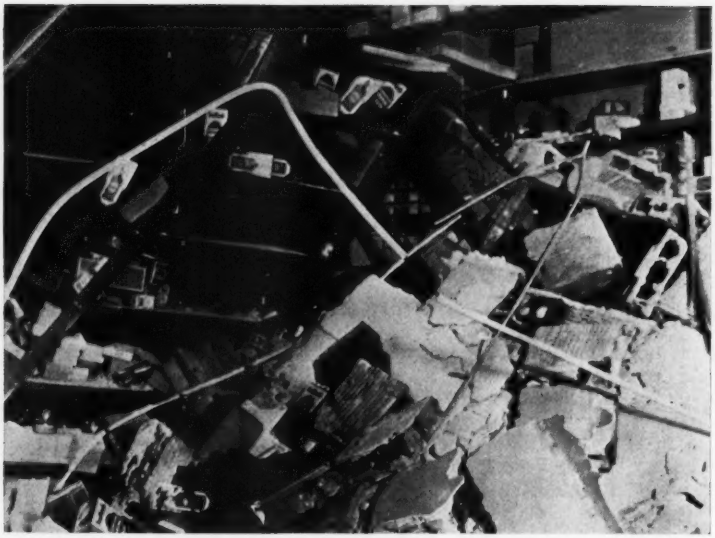
The fire originated shortly after 8 P.M. in the first sub-basement of the Madison Avenue section in the premises of the Thonet-Wanner Co., Inc., in a room used for designing and drafting and for the storage of antique furniture. Employees had been at work taking inventory of the stock. The fire was discovered by one of them and an alarm sent to the fire department at 8:11 P.M.

The cause of the fire has not been definitely determined. Painters had been at work in the vicinity of the origin of the fire until 5 P.M. and spontaneous ignition of oily rags or the carelessness of a smoker may have been the cause. Examination of wiring after the fire indicated that additions and alterations had been made to the electrical wiring of such character that the fire might have originated from electrical causes.

Because of the large quantity of flammable material present, the fire spread rapidly and according to eyewitnesses was most spectacular viewed from the street. It spread throughout a large portion of the sub-basement floor and to a small extent to the basement above by way of a metal vent duct. Smoke and sparks shot up an elevator shaft and out of the motor housing at the top in such volume that the penthouses on the roof appeared to be burning. But the stubborn battle waged by the firemen below ground kept the actual flames from getting above the basement levels.

An explosion occurred during the early stages of the fire, as evidenced by the accompanying illustration. Reports differ as to whether this was a smoke explosion, or a transformer explosion.

A very small portion of the sub-basement had been sprinklered. These sprinklers were installed for a previous occupant in a cut-off section and remained in place after the partition enclosing the section had been removed.



Keystone

Shop on strect floor, showing damage due to fire and explosion.

Water for these sprinklers was supplied by connections to a street main and by siamese connections on the street, but water had apparently never been turned on.

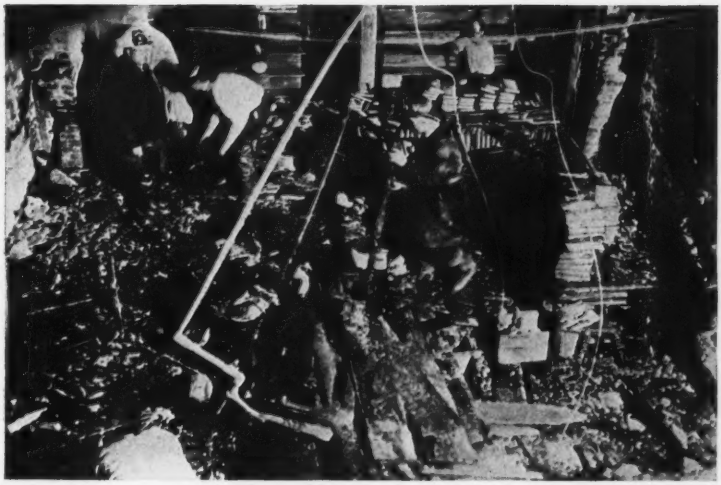
The standpipe system was in serviceable condition, but its outlets were not available because of the dense smoke. It was necessary, therefore, for the fire department to depend upon hose lines from the street and great difficulty was experienced in getting through the smoke to reach the seat of the fire. The fire department made a very creditable showing in preventing the fire from assuming more serious proportions. Several firemen were overcome by the smoke while attempting to extinguish the blaze and were rescued by their comrades.

Loss of Life and Injuries.

Two persons lost their lives. One was an elevator operator, who was suffocated by smoke when his car stalled between the fourth and fifth floors. The car stalled when the electric current failed due to the fire attacking the insulation of the power cables and causing a short circuit or, as stated by the New York *Times,* when Chief Kenlon, knowing of the presence of high-tension power lines, ordered the power shut off in the basement of the hotel.*

The other person, an elderly lady, succumbed due to the exertion caused by descending from an upper floor of the building by way of the stairway after the failure of the power supply to the elevators. She was ill in bed in

*It is reported that fuses had blown out before the power was ordered shut off.



Keystone

Sub-basement view, showing character of the damage.

her apartment on the eleventh floor when the alarm sounded. Her husband helped her to the elevator, but it went down only one floor when the power failed. She then walked down ten flights and collapsed when she reached Madison Avenue. Death was due to an overtaxed heart.

An employee of the New York Central Railroad Company was injured when portions of a tile partition were blown against him by a back draft, as he was attempting to open switches on a board in the sub-basement.

The Damage.

The damage to the building was confined for the most part to the floor on which the fire originated. Electrical wiring, switchboards, partitions, wall and ceiling finish, piping and the doors opening to one elevator shaft were badly damaged. Damage to the building on floors other than where the fire occurred was not serious and, except for a small portion of trim burned in the basement, was due to smoke and water. The total building loss was estimated at $212,500.

The greater portion of the stock of the Thonet-Wanner Company in the sub-basement was damaged by the fire and such stock as was not burned was seriously affected by smoke and water. The stock of this concern on the floor below (second sub-basement) was damaged by water. The loss to this company was estimated at $75,000 with water damage to other tenants amounting to $2500.

Conclusions.

The difficulties confronting the fire department in extinguishing a fire below grade by the use of hose lines operated from the street are obvious.

Even a small fire creates enough smoke to make it difficult for them to work effectively and a fire starting in a considerable quantity of readily flammable material a number of floors below the ground, may easily gain sufficient headway to resist their best efforts for a considerable period, unless there is a reliable fire extinguishing system installed. Such extinguishing system should preferably consist of properly installed and maintained automatic sprinklers, especially when the floors above the business portion are occupied for dwelling purposes. Had a proper sprinkler system been installed on the lower floors, it is reasonable to assume that this fire would have been extinguished or controlled in its incipiency with saving of both life and property.

Fires in Which There Was Loss of Life.

These notes are intended to point out typical conditions under which loss of life has occurred that they may be known and guarded against.

Automobile Accident.

WICHITA, KANSAS, NOVEMBER 17, 1929. Three persons were killed and one was injured when the light sedan in which they were riding struck a parked oil field truck, causing the gasoline tank of the passenger car to ignite and converting the interior of the car into a seething mass of flames. A long iron rod extending out from the rear end of the parked truck smashed through the radiator of the sedan and punctured the gasoline tank. Gasoline from the tank ignited from hot motor. Only one of the passengers was able to break his way out of the car. (H-29282.)

Christmas Tree Near Fireplace.

HACKENSACK, N. J., JANUARY 1, 1930. The lives of two elderly people were lost in a fire believed to have been caused by sparks from an open fireplace in the living room which ignited a Christmas tree near-by. The grandfather carried his two grandsons to a balcony over the front piazza and they were saved. He then returned to the room, where he collapsed, and his wife was overcome in trying to save him. Both were found dead when the firemen were able to enter the room. (L-565.)

Children Left Alone in House.

PHOENIX, N. Y., MARCH 7, 1930. Two little girls were trapped and burned to death by a fire in their home. They were alone in the house at the time the fire occurred, and were playing in a room, the only escape from which was through the room in which an overheated stove had started the fire. (L-514.)

WATERBURY, CONN., FEBRUARY 18, 1930. Two children died of suffocation when fire occurred in their home while they were alone. They were asleep and their mother had left them to visit her sick father. The fire started from an overheated coal stove. (L-523.)

JAY-PEE, IDAHO, FEBRUARY 10, 1930. Two baby boys, left alone while their parents attended a party next door, were burned to death when the house caught fire. The children's fathers were burned as they carried their dying babies from the building. (L-532.)

WESTFIELD, MASS., FEBRUARY 7, 1930. Three children, all under four years of age, lost their lives when fire swept through the five-room house in which they lived. Their mother had gone to a neighbor's house to use the telephone when the fire occurred. (L-535.)

ORMSTOWN, P. Q., JANUARY 1, 1930. Six children, members of two families, were burned to death when fire destroyed the house in which they were sleeping. The parents had left the children together in one house while they went out for the evening. An explosion of an oil lamp started the blaze. (L-566.)

Child Playing with Matches.

WASHINGTON, D. C., JANUARY 29, 1930. A five-year-old boy, left alone in the apartment in which he lived, procured a box of matches and began lighting them. His clothing became ignited and he ran screaming from the apartment. Other occupants of the building extinguished the child's flaming garments, but not before he had received fatal injuries. (L-539.)

Child Poured Gasoline on Fire.

ANNAPOLIS, MD., FEBRUARY 20, 1930. A small boy was fatally burned because he wanted to see a "big fire." The five-year-old child secured a can containing a small amount of gasoline and poured the fluid on the embers of a dying blaze that had been started by his grandfather. Flames enveloped the child's clothing and he was badly burned before help came. (L-522.)

Cleaning Clothes with Gasoline.

HASTINGS, MINN., FEBRUARY 2, 1930. A mother and daughter died of burns as the result of an accident caused by cleaning clothes with gasoline. The mother was cleaning the clothes on her back porch. Fainting from the fumes, she fell, upsetting the vessel containing the gasoline and her clothes became saturated with it. Her daughter carried her into the house, passing the kitchen stove in which there was a fire. The gasoline fumes ignited, setting the mother's clothes afire. The daughter then carried her mother out of the house and in so doing she also received burns which were fatal. (L-537.)

Clothing Ignited from Gas Stove.

NEW YORK, N. Y., MARCH 10, 1930. A young woman was fatally burned when her clothing caught fire while she was cooking at the gas stove in the kitchen of her apartment. She ran to the bathroom, climbed into the tub and turned on the water, but forgot to close the drain to keep the water in the tub. She died of the burns within a few minutes after the accident. (L-512.)

Clothing Ignited.

SPRINGFIELD, MASS., FEBRUARY 17, 1930. A woman died of burns received when her dress caught fire at her home. Her father lighted his pipe

with a piece of newspaper and then threw the paper into the coal hod near the stove. The woman, not noticing the flaming paper, approached the hod and her clothes caught fire. (L-527.)

Floor Wax Explosion.

SAVANNAH, GA., DECEMBER 30, 1929. Two men were killed and a third was severely burned, as the result of a fire in the linen room of a hospital, caused by the explosion of a drum containing floor wax. The explosion occurred when one of the three men in the room tilted a 50-gallon drum and struck a match to see how much floor wax it contained. Patients in the hospital were moved to near-by homes during the fire, which was confined to the linen room. (H-29291.)

Fuse Bridged with Pennies.

LAS VEGAS, N. M., JANUARY 24, 1930. Two pennies which were placed across a fuse gap in order to supply the house with lights after the fuses had blown out, were responsible for a fire which took the lives of two children. (L-547.)

Illuminating Gas Explosion.

PITTSBURGH, PA., FEBRUARY 11, 1930. A gas explosion and fire caused the death of a woman when she struck a match to relight a gas burner which was blown out while she was out of the room. Her clothing was ignited by the explosion. (L-533.)

Hot Bricks Placed in Bed.

MANSFIELD, MASS., JANUARY 21, 1930. An elderly woman was burned to death in her bed in a fire which was believed to have been started by hot bricks which she placed there. (L-551.)

Playing with Explosives.

ALBRIGHT, W. VA., MARCH 1, 1930. One young man was burned to death and another only saved himself by jumping into a swamp when they touched a lighted match to some cans of blasting powder which they found. Their clothing was instantly ignited by the blast which occurred. (L-520.)

Re-entering Burning Building.

STATE COLLEGE, PA., MARCH 3, 1930. After assisting his wife to escape, a minister returned to their apartment to bring out some of their belongings. He was overcome by smoke and died before firemen were able to locate him and bring him out. (L-519.)

PHOENIX, ARIZ., MARCH 5, 1930. A woman was burned to death when the home of her daughter, whom she was visiting, was destroyed by fire. After escaping from the building, she returned to save her diamonds and lost her life. (L-516.)

PLYMOUTH, MASS., JANUARY 19, 1930. A man was burned to death when a frame building, used as a lodging place for workers in the cranberry bogs, was destroyed by a fire starting from an overheated stove. All the employees escaped but one man, who returned to save his belongings. (L-553.)

Starting Fire with Kerosene.

INDIANAPOLIS, IND., JANUARY 7, 1930. An attempt to kindle a fire with kerosene caused the death of five members of one family. The father poured kerosene on the stove fire. The blaze spread so quickly that he, his wife and three children, were burned to death. Six months old twins were the only survivors. (L-559.)

Tank Truck Struck by Train.

BAKERSFIELD, CALIF., DECEMBER 9, 1929. Three men were killed when a passenger train struck a gasoline tank truck and trailer. The truck and trailer which had been stalled on the railroad tracks exploded, spraying gasoline over the engine and cars. The clothing of the engineer, fireman and a mail clerk were set afire and they lost their lives. The passengers escaped from the flaming cars, and the driver of the oil truck also escaped. (H-29283.)

Trapped in Burning Home.

WINSTEAD, CONN., MARCH 14, 1930. A man received fatal burns while aiding his young nephews and nieces to escape from an early morning fire in their home. After the children had escaped the uncle found himself trapped and was forced to jump from a second-story window. (L-511.)

FREDERICK, COLO., JANUARY 28, 1930. Seven persons were burned to death when fire destroyed a two-room house occupied by a miner's family. The fire started from an overheated stove when the family was asleep. The father was away, working on a night shift. The mother and five children lost their lives by suffocation and burns, while a man who broke into the house trying to save the family was burned to death. (L-541.)

Suffocated in Fire.

SPRINGFIELD, MASS., FEBRUARY 18, 1930. A night fire, which started in the cellar of a duplex dwelling from an overheated furnace, took the life of a woman sleeping on the second floor, and caused injuries to several other persons. The woman who lost her life died as the result of suffocation. Another woman was severely burned when flames burst forth as she opened the cellar door while trying to locate the source of the smoke. (L-525.)

Annual Sprinkler Tables.

Statistics of Fires in Properties Having Automatic Sprinkler Protection.

NOTE.—These tabulations are made at the close of each year with the object of furnishing a basis upon which the virtues of the automatic sprinkler as an extinguishing agent can be estimated.

Section I is devoted to fires in which the behavior of sprinklers was, for the reasons given, unsatisfactory.

Section II is a statistical record of all reports of sprinkler fires in the files of the Association upon which the information obtained is sufficiently complete for statistical purposes.

In each table the results of the current year ending February 1, 1930, are given, and these are compared with the results of the total thirty-four year record ending at that time.

The annual sprinkler tabulation is published this year for the thirty-fourth consecutive year. The tables show the actual fire experience with automatic sprinkler equipments in over forty-two thousand fires. This is not intended as a complete statistical record of fires occurring in sprinklered properties; it includes only those fires reported to the Department of Fire Record in sufficient detail to give the data necessary for the tables. This is probably only a fraction of the total number of fires occurring in buildings under sprinkler protection, but with a total of 42,000 fires in the record and current reports being received at the rate of approximately two thousand a year, there can be no doubt that this summary as a whole is typical and completely representative. An exception to this statement may be made in the case of the detailed records of experience in some occupancies where only a comparatively small number of fires are reported. In order to maintain the continuity of the tables from year to year it is necessary to have every occupancy classification appear, even though there be but one sprinklered fire reported. It is obvious, however, that conclusions should not be drawn as to the effectiveness of sprinklers in an occupancy where the number of fires reported is so small that the efficiency percentage may be distorted by the results of some one unusual fire.

The several tables showing sprinkler performance are divided into columns of cases where sprinklers "extinguished fire" and cases where sprinklers "held fire in check," both of these being classed as satisfactory performance. The distinction between these two classifications is necessarily more or less arbitrary, depending upon the judgment of the original inspector. The great majority of the fires in the "held in check" columns are cases where hose streams or chemicals were used to extinguish fire in spaces which water from the sprinkler did not reach because of obstructions to distribution, concealed

spaces or unsprinklered portions, but where sprinklers functioned satisfactorily in preventing the spread of fire.

In preparing these tables it is the fixed policy of the Department of Fire Record never to give the sprinklers the benefit of the doubt. In cases where there is question as to whether a given fire should be classified as "Held in Check" or "Unsatisfactory," it is always placed in the "Unsatisfactory" column. The tables thus give a very conservative picture of the efficiency of sprinklers. Likewise it should be noted that there are doubtless a large number of fires annually which are extinguished by one or two sprinkler heads where no claim for loss is made and where no report reaches the Department of Fire Record. If it were possible to include the reports of all such fires in the tables the total percentage of sprinkler efficiency would approach much nearer to one hundred per cent.

The tables presented this year follow the same general plan and arrangement as in previous years. The following changes in occupancy classification have been made during the past year:

Carbon Works (formerly in Misc.).

Country Clubs, City Clubs } Reclassification of Clubs.

Hotels, Resort Hotels, Rooming and Lodging Houses } Reclassification of Hotels.

Oil Cloth Mfg., Linoleum Mfg. } Reclassification of Oil Cloth and Linoleum Works.

Motion Picture Studios, Motion Picture Exchanges, Motion Picture Theatres } Reclassification of Motion Pictures (Theatres, Studios, Exchanges).

The total number of sprinklered fire reports received during the past year was 3,004. The number of fires in which the sprinklers were not a factor was 782. This includes fires occurring in unsprinklered portions of buildings which did not extend to the sprinklered portions, or fires occurring in sprinklered portions which were discovered and extinguished by other means before there was sufficient heat to open sprinklers.

SECTION I.

Summary of Unsatisfactory Sprinkler Fires.

	1929-1930 No. of Fires	1929-1930 Per Cent	1897-1930 incl. No. of Fires	1897-1930 incl. Per Cent
Water shut off sprinklers	27	33.3	565	31.3
Generally defective equipment	10	12.3)		
Unsprinklered portions	5	6.1)	347	19.3
Defective water supply or supplies	8	10.0	161	9.0
Sprinkler system crippled due to freezing	4	5.0	48	2.7
Slow operation of dry system or defective valve	5	6.1	52	2.9
Slow or defective operation of high test heads	..	..	25	1.4
Faulty building construction, concealed spaces, vertical openings, etc.	4	5.0	90	5.0
Obstruction to distribution	4	5.0	97	5.4
Hazard of occupancy too severe for average sprinkler equipment	5	6.1	106	5.9
Explosion crippled sprinkler system	..	..	81	4.5
Exposure or conflagration	1	1.2	75	4.2
Plugged heads (included with Miscellaneous prior to 1921)	8	9.9	23	1.3
Miscellaneous	..	..	128	7.1
Total	81		1798	

Fires in Which Failure Was Due to Water Shut Off Sprinklers.

	1929-1930 No. of Fires	1897-1930 No. of Fires
Water shut off for unknown reason, neglect or carelessness	7	182
Water shut off before fire was out or fire rekindled	7	92
Water shut off due to accidents or repairs	3	92
Water shut off to prevent freezing	5	132
Water shut off, probably incendiary	1	9
Water shut off, leaky dry system	1	12
Water shut off, defective gate valve	..	9
Water shut off, miscellaneous	3	37
Total	27	565

SECTION II.

Annual Revision of Sprinkler Fire Tables.

In the following tables is given a summary of fires occurring in properties equipped with automatic sprinklers. The total number of such fires reported during the past year was 3004, which includes 782 fires where no sprinklers were opened. Several reports were also received in which the data were incomplete, and these were not used in the summary. It may be noted that the total number of fires does not agree throughout all the tables. This is because some of the reports of fires prior to 1909 were not considered sufficiently complete to include in all the tables, and hence appear in some tables, but not in others.

Table No. 1—Number of Sprinklers Operating.

No. of Fires, 1929-1930.

No. of Sprinklers Operating	Wet	%	Dry	%	No Data	Total	%
1	665	45.6	72	19.6	118	855	39.2
2	295	20.1	51	13.9	52	398	18.3
3	122	8.4	41	11.2	30	193	8.9
4	82	5.6	34	9.3	27	143	6.5
5	48	3.4	17	4.6	16	81	3.7
6	35	2.4	14	3.8	21	70	3.1
7	30	2.1	15	4.1	13	58	2.7
8	21	1.4	8	2.2	14	43	2.0
9	18	1.2	9	2.5	6	33	1.5
10	19	1.3	6	1.6	10	35	1.6
11	12	.8	3	.8	2	17	.8
12	4	.3	6	1.6	11	21	1.0
13	3	.2	9	2.5	1	13	.6
14	9	.7	1	.3	4	14	.6
15	5	.4	4	1.1	6	15	.7
16-20	28	1.9	18	4.9	10	56	2.6
21-25	20	1.4	10	3.0	3	33	1.5
26-30	9	.7	11	3.2	4	24	1.1
31-35	1	.1	4	1.1	4	9	.4
36-40	4	.3	4	1.1	3	11	.5
41-50	4	.3	4	1.1	3	11	.5
51-75	6	.5	5	1.3	3	14	.6
76-100	3	.2	7	1.9	..	10	.5
Over 100	5	.4	8	2.2	1	14	.6
No Data	4	.3	4	1.1	3	11	.5
Total	1452	100.0	365	100.0	365	2182	

No. of Fires, 1897-1930, inclusive.

No. of Sprinklers Operating	Wet	%	Dry	%	No Data	Total	%
1	12609	37.4	1413	19.9	204	14226	33.9
2	6206	18.4	950	13.3	94	7250	17.2
3	3322	9.9	607	8.5	58	3987	9.5
4	2331	7.0	516	7.2	48	2895	6.9
5	1425	4.2	331	4.6	31	1787	4.2
6	1153	3.4	318	4.5	34	1505	3.5
7	800	2.4	241	3.4	20	1061	2.5
8	755	2.2	207	2.9	23	985	2.3
9	491	1.5	168	2.4	13	672	1.6
10	453	1.3	142	2.0	22	617	1.5
11	326	1.0	120	1.7	6	452	1.1
12	360	1.1	147	2.1	18	525	1.2
13	211	.6	110	1.5	9	330	.8
14	250	.7	107	1.5	8	365	.9
15	207	.6	103	1.4	8	318	.8
16-20	708	2.1	311	4.4	23	1042	2.5
21-25	420	1.2	231	3.2	9	660	1.6
26-30	293	.9	161	2.3	13	467	1.1
31-35	177	.5	103	1.4	7	287	.7
36-40	162	.5	95	1.3	7	264	.6
41-50	196	.5	122	1.7	6	324	.8
51-75	280	.8	174	2.4	5	459	1.1
76-100	124	.4	94	1.3	5	223	.5
Over 100	400	1.2	301	4.2	13	714	1.7
No Data	80	.2	67	.9	473	620	1.5
Total	33739	100.0	7139	100.0	1157	42035	100.0
Water shut off sprinklers						337	
Total						42372	

Table No. 2—Number of Sprinklers Operating.

No. of Sprinklers Operating	No. of Fires, 1897-1930, inclusive. Wet	%	Dry	%	No Data	Total	%
1	12609	37.4	1413	19.9	204	14226	33.9
2 or less	18815	55.8	2363	33.1	298	21476	51.2
3 or less	22137	66.1	2970	40.3	356	25463	60.6
4 or less	24468	72.6	3486	48.8	404	28358	67.5
5 or less	25893	76.8	3817	53.4	435	30145	71.7
6 or less	27046	77.4	4135	57.9	469	31650	75.2
7 or less	27846	82.6	4376	61.4	489	32711	78.0
8 or less	28601	85.0	4583	64.4	512	33696	80.4
9 or less	29092	86.4	4751	66.5	525	34368	81.8
10 or less	29545	87.6	4893	68.6	547	34985	83.3
11 or less	29871	88.8	5013	70.3	553	35437	84.4
12 or less	30231	89.6	5160	72.4	571	35962	85.5
13 or less	30442	90.4	5270	74.0	580	36292	86.5
14 or less	30692	91.0	5377	75.3	588	36657	87.4
15 or less	30899	91.6	5480	76.7	596	36975	88.0
20 or less	31607	93.8	5791	79.8	619	38017	90.6
25 or less	32027	95.2	6022	84.5	628	38677	92.3
30 or less	32320	95.8	6183	86.6	641	39144	93.2
35 or less	32497	96.6	6286	88.0	648	39431	93.7
40 or less	32659	96.9	6381	89.4	655	39695	94.5
50 or less	32855	97.5	6503	91.1	661	40019	95.6
75 or less	33135	98.2	6677	93.5	666	40478	96.4
100 or less	33259	98.6	6771	94.9	671	40701	97.0
Over 100	400		301		13	714	
No data	80		67		473	620	
Total	33739		7139		1157	42035	
Water shut off sprinklers						337	
Total						42372	

Table No. 3—Effect of Sprinklers.

	1929-1930 No. of Fires	%	1897-1930 No. of Fires	%
Practically or entirely extinguished	1530	69.0	28485	67.5
Held fire in check	611	27.5	12048	28.4
Total Satisfactory	2141	96.5	40533	95.9
Unsatisfactory	81	3.5	1798	4.1
Total	2222		42331	

Table No. 4—Effect of Sprinklers by Class of Occupancy.

	Extinguished Fire		Held Fire in Check		Total Satisfactory		Unsatisfactory		Total No. of Fires
	No.	%	No.	%	No.	%	No.	%	
Abrasive Works	13	65.0	5	25.0	18	90.0	2	10.0	20
Aeroplane Factories	4	45.0	5	55.0	9	100.0	..	..	9
Agricultural Implement Mfg.	62	56.4	43	39.1	105	95.5	5	4.5	110
Alcohol Distilleries	..	..	1	100.0	1	100.0	..	..	1
Aluminum Works	3	50.0	2	33.3	5	83.3	1	16.7	6
Amusement Resorts	3	75.0	1	25.0	4	100.0	..	..	4
Apartment Houses	85	85.0	15	15.0	100	100.0	..	..	100
Artificial Flower Mfg.	15	100.0	..	..	15	100.0	..	..	15
Artificial Leather Mfg.	19	41.3	24	52.2	43	93.5	3	6.5	46
Asbestos Works	15	51.8	11	38.0	26	89.8	3	10.2	29
Automobile and Bicycle Factories	214	..	134	..	348	..	18	..	366
Automobile Paint Shops	9	90.0	1	10.0	10	100.0	..	..	10
Awning Factories	7	70.0	3	30.0	10	100.0	..	..	10
Bag Factories	40	63.5	20	31.8	60	95.3	3	4.7	63
Bakeries	134	73.7	40	21.9	174	95.6	8	4.4	182
Basket Factories	10	83.5	2	16.5	12	100.0	..	..	12
Battery Mfg. Plants	25	67.6	11	29.7	36	97.3	1	2.7	37
Bolt, Nut and Screw Works	23	60.6	13	34.2	36	94.8	2	5.2	38
Bottle Caps and Seals Mfg.	28	53.8	24	46.2	52	100.0	..	..	52
Bottling Works	6	66.7	2	22.1	8	88.8	1	11.2	9
Bowling Alleys, Pool Rooms, etc.	12	92.4	1	7.6	13	100.0	..	..	13
Braid Mills	46	79.3	10	17.2	56	96.5	2	4.5	58
Brass Works	74	71.8	26	25.2	100	97.0	3	3.0	103
Breweries	5	83.4	1	16.6	6	100.0	..	..	6
Broom Factories	14	58.3	8	33.3	22	91.6	2	8.4	24
Brush Factories	27	69.2	12	30.8	39	100.0	..	..	39
Buildings Under Construction	..	..	2	100.0	2	100.0	..	..	2
Button Factories	71	83.5	12	14.1	83	97.6	2	2.4	85
Candle Factories	7	50.0	7	50.0	14	100.0	..	..	14
Candy Factories	184	72.5	61	24.0	245	96.5	9	4.5	254
Canning Factories	18	64.3	7	25.0	25	89.3	3	10.7	28
Carbon Works	5	83.4	1	16.6	6	100.0	..	..	6
Car Houses	37	44.6	38	45.8	75	90.4	8	9.6	83
Car Works	87	61.3	50	35.2	137	96.5	5	3.5	142
Carpet and Rug Mills	183	63.1	97	33.4	280	96.5	10	3.5	290
Carriage and Auto Body Factories	140	58.3	79	32.9	219	91.2	21	8.8	240
Cement and Plaster Works	11	73.4	2	13.3	13	86.7	2	13.3	15
Cereal Mills	37	62.7	14	23.8	51	86.5	8	13.5	59
Chemical and White Lead Works	147	58.6	85	36.6	232	92.2	19	7.8	251
Clock and Watch Factories	10	76.9	3	23.1	13	100.0	..	..	13
Clothing Factories	1903	85.8	295	13.3	2198	99.1	17	.9	2215
City Clubs	14	70.0	4	20.0	18	90.0	2	10.0	20
Country Clubs	6	60.0	4	40.0	10	100.0	..	..	10
Coal and Wood Storage	2	40.0	3	60.0	5	100.0	..	..	5
Coffee and Spice Mills	80	70.8	29	25.7	109	96.5	4	3.5	113
Coffin and Casket Factories	67	72.0	21	22.6	88	94.6	5	5.4	93
Cold Storage Plants	9	64.3	5	35.7	14	100.0	..	..	14

	Extinguished Fire		Held Fire in Check		Total Satisfactory		Unsatisfactory		Total No. of Fires
	No.	%	No.	%	No.	%	No.	%	
Cooperage Plants	55	59.1	27	29.0	82	88.1	11	11.9	93
Cordage Works	235	64.6	116	31.9	351	96.5	13	4.5	364
Cork Factories	33	50.8	27	41.5	60	92.3	5	7.7	65
Corset Factories	11	68.8	4	25.0	15	93.8	1	6.2	16
Cotton Gins	8	61.5	5	38.5	13	100.0	..	..	13
Cotton Mills	4829	62.3	2821	36.4	7650	98.7	103	1.3	7753
Cotton Seed Oil Mills	40	48.2	29	34.9	69	83.1	14	16.9	83
Cotton Warehouses	163	46.0	162	45.7	325	91.7	29	8.3	354
Cutlery and Tool Mfg	30	62.5	16	33.3	46	95.8	2	4.2	48
Dairies and Creameries	5	100.0	..	..	5	100.0	..	..	5
Department Stores	574	78.5	136	18.6	710	97.1	22	2.9	732
Distilleries	10	62.5	5	31.2	15	93.7	1	6.3	16
Doll Factories	57	62.0	35	38.0	92	100.0	..	..	92
Drug Mfg. and Warehouses	220	80.1	50	18.2	270	98.3	5	1.7	275
Dry Cleaning Establishments	12	57.2	9	42.8	21	100.0	..	..	21
Dry Goods Stores	328	85.8	50	13.1	378	98.9	5	1.1	383
Dwellings	..	..	..	..	..	..	1	100.0	1
Dyeing, Bleaching and Finishing	200	53.6	158	42.4	358	96.0	15	4.0	373
Electrical Appliance Mfg	355	67.9	157	30.0	512	97.9	11	2.1	523
Electric Light and Power Plants	6	37.5	7	43.7	13	81.2	3	18.8	16
Elevators, Grain	33	37.9	31	35.6	64	73.5	23	26.5	87
Excelsior Factories	30	66.7	11	24.4	41	91.1	4	8.9	45
Fertilizer Plants	30	65.2	12	26.1	42	91.3	4	8.7	46
Fireworks Plants	..	..	2	100.0	2	100.0	..	..	2
Flax and Linen Mills	41	53.9	35	46.1	76	100.0	..	..	76
Flour and Grist Mills	78	55.3	38	26.9	116	91.2	25	8.8	141
Forge and Smithy	21	70.0	7	23.3	28	93.3	2	6.7	30
Foundries	198	58.6	124	36.7	322	95.3	16	4.7	338
Fruits, Dried, Plants	1	100.0	..	..	1	100.0	..	..	1
Fur Mfg	130	93.5	7	5.2	137	98.7	2	1.3	139
Furniture Factories	817	66.2	322	26.1	1139	92.3	97	7.7	1236
Furniture Stores	98	77.8	22	17.5	120	95.3	6	4.7	126
Garages	364	68.8	158	29.8	522	98.6	8	1.4	530
Garbage Reduction Plants	3	60.0	1	20.0	4	80.0	1	20.0	5
Gas Works	2	40.0	2	40.0	4	80.0	1	20.0	5
General Stores	27	78.0	8	22.0	35	100.0	..	..	35
Glass Factories	76	54.7	47	33.8	123	88.5	16	11.5	139
Glove Factories	16	77.2	4	19.0	20	96.2	1	3.8	21
Glue Factories	10	45.5	9	40.9	19	86.4	3	13.6	22
Groceries	159	77.1	38	18.4	197	95.5	9	4.5	206
Gum Mfg	6	86.0	1	14.0	7	100.0	..	..	7
Hair Works	21	72.8	6	27.2	27	100.0	..	..	27
Hardware Stores	108	81.8	22	16.7	130	98.5	2	1.5	132
Harness and Fancy Leather Mfg	167	83.5	31	15.5	198	99.0	2	1.0	200
Hat Factories	299	79.0	67	17.7	366	96.7	13	3.3	379
Hatters' Fur Works	20	55.6	10	27.8	30	83.4	6	16.6	36
Hotels	58	76.4	15	19.7	73	96.1	3	3.9	76
Resort Hotels	4	50.0	4	50.0	8	100.0	..	..	8
Ice Mfg. Plants	2	66.7	1	33.3	3	100.0	..	..	3

	Extinguished Fire		Held Fire in Check		Total Satisfactory		Unsatisfactory		Total No. of Fires
	No.	%	No.	%	No.	%	No.	%	
Ice Cream Factories	2	28.6	5	71.4	7	100.0	..	..	7
Idle Property	2	10.0	3	15.0	5	25.0	15	75.0	20
Incandescent Lamp Works	25	65.8	13	34.2	38	100.0	..	..	38
Institutions	19	68.0	8	28.6	27	96.6	1	3.4	28
Insulated Wire Works	46	64.8	24	33.8	70	98.6	1	1.4	71
Jewelry Factories	182	85.0	26	12.1	208	97.1	6	2.9	214
Junk Shops	24	73.6	8	24.2	32	97.8	1	2.2	33
Knitting Mills, Cop Yarn	68	67.5	26	25.8	94	93.3	7	6.7	101
Knitting Mills, Full Process	544	65.6	256	30.9	800	96.5	27	3.5	827
Lamp Shade Factories	28	93.5	2	6.5	30	100.0	..	..	30
Laundries	113	73.5	37	24.0	150	97.5	4	2.5	154
Lead Pencil Factories	18	69.2	7	26.9	25	96.1	1	3.9	26
Linoleum Works	27	25.7	62	59.0	89	84.7	16	15.3	105
Linseed Oil Works	21	51.3	12	29.3	33	80.6	8	19.4	41
Lumber Yards	2	100.0	..	..	2	100.0	..	..	2
Macaroni Factories	8	66.7	2	16.6	10	83.3	2	16.7	12
Machine Shops and Works	362	68.6	141	26.8	503	95.3	24	4.7	527
Mail Order Houses	46	92.0	4	8.0	50	100.0	..	..	50
Match Factories	62	75.5	16	19.5	78	95.0	4	5.0	82
Mattress Factories	514	68.7	221	29.5	735	98.2	14	1.8	749
Mercantile (Miscellaneous)	898	81.6	175	15.9	1073	97.5	30	2.5	1103
Metal Reduction Plants	11	68.8	5	31.2	16	100.0	..	..	16
Metal Workers†	1047	62.8	547	32.9	1594	95.7	70	4.3	1664
Mining Property	2	50.0	1	25.0	3	75.0	1	25.0	4
Mirror Mfg.	17	89.6	2	10.4	19	100.0	..	..	19
Miscellaneous	448	73.9	133	21.9	581	95.8	26	4.2	607
Morocco Leather	57	50.5	44	38.9	101	89.4	12	10.6	113
Motion Picture Exchanges	42	84.0	6	12.0	48	96.0	2	4.0	50
Motion Picture Studios	16	76.2	5	23.8	21	100.0	..	..	21
Motion Picture Theatres	52	80.0	8	12.3	60	92.3	5	7.7	65
Multiple Occupancy	22	57.9	12	31.6	34	89.5	4	10.5	38
Munition Plants	25	44.6	22	39.3	47	83.9	9	16.1	56
Musical Instrument Factory	150	69.2	60	27.6	210	96.8	7	3.2	217
Office Buildings	70	87.5	10	12.5	80	100.0	..	..	80
Oil Cloth Works	26	47.3	22	40.0	48	87.3	7	12.7	55
Oil Clothing Factories	14	70.0	5	25.0	19	95.0	1	5.0	20
Oil Refineries—Animal	3	50.0	3	50.0	6	100.0	..	..	6
—Mineral	6	60.0	4	40.0	10	100.0	..	..	10
—Vegetable	11	44.0	10	40.0	21	84.0	4	16.0	25
Optical Works	14	53.8	12	46.2	26	100.0	..	..	26
Packing Houses	177	71.3	62	25.0	239	96.3	9	3.7	248
Paint and Varnish Works	258	65.7	121	30.7	379	96.4	14	3.6	393
Paper Box and Paper Products	289	76.7	81	21.4	370	98.1	7	1.9	377
Paper Coating Mills	20	71.5	5	17.9	25	89.4	3	10.6	28
Paper Mills	525	49.6	433	41.2	958	90.8	95	9.2	1053
Patent Leather (see also Tanneries)	13	37.2	17	48.5	30	85.7	5	14.3	35
Peanut Roasting Plants	1	50.0	1	50.0	2	100.0	..	..	2

† See note on Metal Workers under Table No. 5.

	Extinguished Fire		Held Fire in Check		Total Satisfactory		Unsatisfactory		Total No. of Fires
	No.	%	No.	%	No.	%	No.	%	
Phonograph Works	30	71.4	11	26.2	41	97.6	1	2.4	42
Photograph Establishments	50	73.5	17	25.0	67	98.5	1	1.5	68
Picture Frame Mfg	51	66.3	20	26.0	71	92.3	6	7.7	77
Piers and Wharves	13	46.4	13	46.4	26	92.8	2	7.2	28
Plumbers' Supplies	34	72.3	12	25.5	46	97.8	1	2.2	47
Potteries	53	63.2	25	29.7	78	92.9	6	7.1	84
Printing and Lithographing	940	81.7	190	16.5	1130	98.2	20	1.8	1150
Public Buildings	2	66.7	1	33.3	3	100.0	..	..	3
Pulp Mills	37	34.2	46	42.6	83	76.8	25	23.2	108
Pyroxylin Plastic Mfg. & Fabricat'g	204	66.1	74	23.9	278	90.0	31	10.0	309
Radios and Accessories	37	84.2	5	11.3	42	95.5	2	4.5	44
Railroad Property	3	25.0	8	66.7	11	91.7	1	8.3	12
Restaurants	99	71.6	36	26.1	135	97.7	3	2.3	138
Rice Mills	2	33.3	1	16.7	3	50.0	3	50.0	6
Rolling, Wire and Tube Mills	46	56.9	32	39.5	78	96.4	3	3.6	81
Roofing Works	40	41.2	48	49.5	88	90.7	9	9.3	97
Rooming and Lodging Houses	7	87.4	..	..	7	87.4	1	12.6	8
Rubber Cloth Factories	41	58.6	26	37.2	67	95.8	3	4.2	70
Rubber Reclaiming Works	10	31.2	15	46.9	25	78.1	7	21.9	32
Rubber Mills	195	49.4	179	45.4	374	94.8	21	5.2	395
Salt Works	2	50.0	2	50.0	4	100.0	..	..	4
Saw and Planing Mills	102	41.6	84	34.3	186	75.9	59	24.1	245
Schools	23	79.4	6	21.6	29	100.0	..	..	29
Ships and Shipyards	9	53.0	7	41.1	16	94.1	1	5.9	17
Shoddy Mills	249	66.8	102	28.4	351	97.2	22	2.8	373
Shoe Factories	803	73.5	247	22.7	1050	96.2	40	3.8	1090
Shoe Mfg. Accessories	79	68.2	33	28.4	112	96.6	4	3.4	116
Shoe Stores	71	89.1	8	10.1	79	100.0	..	..	79
Silk Mills	145	79.3	33	18.0	178	97.3	5	2.7	183
Skin Mfg. (see also Tanneries)	13	68.4	5	26.3	18	94.7	1	5.3	19
Smelting and Refining	2	40.0	3	60.0	5	100.0	..	..	5
Soap Manufacturing	45	72.6	14	22.6	59	95.2	3	4.8	62
Stables	17	74.0	6	26.0	23	100.0	..	..	23
Stamping and Sheet Metal Works	125	57.3	78	35.7	203	93.0	15	7.0	218
Starch and Glucose Works	14	53.8	4	15.4	18	69.2	8	30.8	26
Sugar Refineries	35	54.8	26	40.6	61	95.4	3	4.6	64
Tanneries	62	53.0	47	40.1	109	93.1	8	6.9	117
Tenant Manufacturing	1044	75.8	272	19.7	1316	95.5	67	4.5	1383
Theatres	76	73.0	21	20.2	97	93.2	7	6.8	104
Tobacco Factories	75	72.8	25	24.2	100	97.0	3	3.0	103
Trunk Factories	39	78.0	8	16.0	47	94.0	3	6.0	50
Umbrella Mfg	16	76.2	4	19.0	20	95.2	1	4.8	21
Vacant Buildings	18	72.2	5	20.0	23	92.2	2	7.8	25
Wall Paper Factories	25	71.4	6	17.1	31	88.5	4	11.5	35
Warehouses	526	71.3	175	23.6	701	94.9	39	5.1	740
Waste and Batting Mills	334	61.0	192	35.0	526	96.0	23	4.0	549
Waste Paper and Rag Shops	135	65.0	67	32.2	202	97.2	6	2.8	208
Weaving Mills	156	67.0	70	30.1	226	97.1	7	2.9	233

	Extinguished Fire		Held Fire in Check		Total Satisfactory		Unsatisfactory		Total No. of Fires
	No.	%	No.	%	No.	%	No.	%	
Window Shade Factories	14	73.6	3	15.8	17	89.4	2	10.6	19
Woodworkers, Class A*	189	55.4	106	31.1	295	86.5	46	13.5	341
Woodworkers, Class B*	182	52.9	130	37.8	312	90.7	32	9.3	344
Woodworkers, Class C*	163	61.3	89	33.4	252	94.7	14	5.3	266
Woodworkers, Class D*	118	57.3	65	31.6	183	88.9	23	11.1	206
Woodworkers, Class E*	229	66.6	101	29.4	330	96.0	14	4.0	344
Woodworkers, Class F*	43	60.6	24	33.8	67	94.4	4	5.6	71
Woolen Mills	1056	69.5	392	25.8	1448	95.3	70	5.7	1518
Wool Scouring Plants	29	65.9	12	27.3	41	93.2	3	6.8	44
Wool Storehouses	29	67.5	11	25.6	40	93.1	3	6.9	43
Worsted Mills	82	58.2	45	31.9	127	90.1	14	9.9	141
Total Sprinkler Fires	28,485		12,048		40,533		1,798		42,331

* See detailed classification of Woodworkers as given under Table 5.

Table 5—Classification of Unsatisfactory Sprinkler Fires by Occupancy.

	Water shut off sprinklers.	Generally defective equipment and unsprinklered portions.	Defective water supply or supplies.	Sprinkler system crippled due to freezing.	Slow operation of dry system or defective dry valve.	Slow or defective operation of high test heads.	Faulty building construction, concealed spaces, vertical openings.	Obstruction to distribution.	Hazard of occupancy too severe for average sprinkler equipment.	Sprinkler system crippled by explosion.	Exposure or conflagration.	Plugged heads.	Miscellaneous.	Total.
Abrasive Works	..	1	..	..	..	..	..	..	..	..	..	..	1	2
Agricultural Implem'ts Mfg.	3	1	..	..	..	..	..	..	1	..	..	..	..	5
Aluminum Works	..	..	..	..	..	..	..	..	..	1	..	..	..	1
Artificial Leather	..	..	..	..	..	..	1	..	..	2	..	..	..	3
Asbestos Plants	..	..	2	..	..	..	..	..	..	1	..	..	..	3
Auto and Bicycle Factories	7	3	1	..	..	..	..	4	..	2	1	..	..	18
Bag Factories	..	..	..	..	..	1	..	1	..	..	..	1	..	3
Bakeries	4	1	..	..	..	..	1	..	..	..	..	..	2	8
Battery Mfg. Plants	1	..	..	..	..	..	..	..	..	..	..	..	..	1
Bolt, Nut and Screw Works	1	1	..	..	..	..	..	..	..	..	..	..	..	2
Bottling Works	..	1	..	..	..	..	..	..	..	..	..	..	..	1
Braid Mills	..	1	..	..	..	..	..	1	..	..	..	..	..	2
Brass Works	1	1	..	..	..	..	..	..	..	..	..	..	1	3
Broom Factories	2	..	..	..	..	..	..	..	..	..	..	..	..	2
Button Factories	..	..	..	2	..	..	..	..	..	..	..	..	..	2
Candy Factories	3	..	..	1	1	..	2	..	1	..	..	..	1	9
Canning Factories	1	..	..	..	1	..	..	..	..	..	1	..	..	3
Car Houses	2	3	1	..	1	..	..	1	..	..	..	..	..	8
Car Works	2	1	..	..	..	..	1	1	..	..	..	..	..	5
Carpet and Rug Mills	4	2	3	..	..	..	..	1	..	..	..	..	..	10
Carriage and Auto Bodies	4	5	3	..	2	..	..	2	1	1	2	1	..	21
Cement and Plaster Works	..	1	..	..	1	..	..	..	..	..	..	..	..	2
Cereal Mills	..	2	1	..	..	..	..	1	..	4	..	..	..	8
Chemical & White Lead Wks.	3	5	..	..	..	..	..	..	5	5	..	..	1	19
Clothing Factories	5	1	2	1	..	..	4	2	..	..	1	1	..	17
City Clubs	1	..	..	..	..	..	1	..	..	..	..	..	..	2

	Water shut off sprinklers.	Generally defective equipment and unsprinklered portions.	Defective water supply or supplies.	Sprinkler system crippled due to freezing.	Slow operation of dry system or defective dry valve.	Slow or defective operation of high test heads.	Faulty building construction, concealed spaces, vertical openings.	Obstruction to distribution.	Hazard of occupancy too severe for average sprinkler equipment.	Sprinkler system crippled by explosion.	Exposure or conflagration.	Plugged heads.	Miscellaneous.	Total.
Coffee and Spice Mills	2	..	..	..	..	..	..	1	..	1	..	..	..	4
Coffin and Casket Factories	2	..	..	1	1	..	1	..	..	..	..	..	..	5
Cooperage Plants	1	4	..	..	..	1	..	4	..	..	1	..	..	11
Cordage Works	4	4	1	1	..	..	..	2	..	..	..	..	1	13
Cork Factories	1	..	1	..	..	..	..	..	1	1	..	..	1	5
Corset Factories	..	..	..	..	..	..	..	..	..	..	1	..	..	1
Cotton Mills	35	25	11	2	2	1	5	2	3	..	..	3	14	103
Cotton Seed Oil Mills	3	5	2	..	..	..	..	..	1	..	..	..	3	14
Cotton Warehouses	14	1	2	..	..	..	1	4	3	..	..	..	4	29
Cutlery and Tool Mfg	1	1	..	..	..	..	..	..	..	..	..	..	..	2
Department Stores	9	7	..	..	1	..	1	1	..	..	2	..	1	22
Distilleries	..	..	..	..	..	..	..	..	..	..	1	..	..	1
Drug Mfg. and Warehouses	..	..	..	..	1	..	..	..	..	..	3	..	1	5
Dry Goods Store	4	..	..	..	..	..	..	1	..	..	..	..	..	5
Dwellings	..	..	..	..	..	..	..	..	..	..	..	..	1	1
Dyeing, Bleach'g & Finish'g	5	3	1	..	1	1	..	1	..	..	1	1	1	15
Electrical Appliances	3	..	2	..	..	..	1	1	..	1	..	1	2	11
Elec. Light & Power Plants	1	1	..	..	..	..	..	1	..	..	..	..	..	3
Elevators, Grain	1	5	5	..	3	..	2	1	..	3	2	..	1	23
Excelsior Factories	..	..	2	..	1	..	..	..	1	..	..	..	..	4
Fertilizer Plants	2	1	..	..	1	..	..	..	..	..	..	..	..	4
Flour and Grist Mills	7	3	2	..	1	..	1	1	2	4	2	..	2	25
Forge and Smithy	..	..	..	..	..	..	..	1	..	..	..	1	..	2
Foundries	11	1	1	..	..	..	1	..	..	2	..	..	..	16
Fur Mfg	..	..	..	..	..	..	1	..	..	..	..	..	1	2
Furniture Factories	30	20	8	4	1	..	4	10	11	1	4	2	2	97
Furniture Stores	4	..	..	..	1	..	1	..	..	..	..	..	..	6
Garages	4	..	..	..	1	..	..	2	..	..	..	..	1	8
Garbage Reduction Plants	1	..	..	..	..	..	..	..	..	..	..	..	..	1
Gas Works	..	1	..	..	..	..	..	..	..	..	..	..	..	1
Glass Factories	4	3	2	1	..	..	2	1	..	..	..	..	3	16
Glove Factories	1	..	..	..	..	..	..	..	..	..	..	..	..	1
Glue Factories	2	..	..	..	..	..	..	..	1	..	..	..	..	3
Groceries	4	..	1	..	1	..	1	..	1	1	..	..	..	9
Hardware Stores	1	..	..	..	..	..	..	..	..	..	..	..	1	2
Harness and Fancy Leather	..	..	1	..	..	..	..	..	..	..	..	..	1	2
Hat Factories	4	4	1	..	1	..	..	1	..	..	..	..	2	13
Hatters' Fur Works	4	..	1	..	..	..	1	..	..	..	..	..	..	6
Hotels	1	1	1	..	..	..	..	..	..	..	..	..	..	3
Idle Property	12	..	..	1	..	..	..	1	1	..	..	..	..	15
Institutions	..	..	..	..	1	..	..	..	..	..	..	..	..	1
Insulated Wire Works	..	1	..	..	..	..	..	..	..	..	..	..	..	1
Jewelry Factories	2	1	..	2	..	..	1	..	..	..	..	..	..	6
Junk Shops	1	..	..	..	..	..	..	..	..	..	..	..	..	1
Knitting Mills, Cop Yarn	1	1	3	..	..	..	..	1	..	1	..	..	..	7
Knitting Mills, Full Process	8	10	5	1	1	..	1	..	..	1	..	..	..	27
Laundries	2	..	1	..	..	..	..	1	..	..	..	..	..	4
Lead Pencil Factories	..	..	..	..	..	..	..	..	..	1	..	..	..	1
Linoleum Works	..	6	..	..	..	..	1	2	7	..	..	..	..	16

	Water shut off sprinklers.	Generally defective equipment and unsprinklered portions.	Defective water supply or supplies.	Sprinkler system crippled due to freezing.	Slow operation of dry system or defective dry valve.	Slow or defective operation of high test heads.	Faulty building construction, concealed spaces, vertical openings.	Obstruction to distribution.	Hazard of occupancy too severe for average sprinkler equipment.	Sprinkler system crippled by explosion.	Exposure or conflagration.	Plugged heads.	Miscellaneous.	Total.
Linseed Oil Works	1	1	..	..	..	..	1	..	1	2	..	2	..	8
Macaroni Factories	2	..	..	..	..	..	..	..	..	..	..	..	..	2
Machine Shops and Works.	15	5	1	1	..	1	..	..	..	1	..	..	..	24
Match Factories	2	..	..	..	..	..	..	..	1	..	..	..	1	4
Mattress Factories	9	2	..	1	..	..	..	2	..	..	..	..	..	14
Mercantile (Miscellaneous)..	11	6	1	2	..	..	3	..	..	1	4	..	2	30
Metal Workers†	21	18	3	1	..	2	5	2	5	5	2	2	4	70
Mining Property	..	1	..	..	..	..	..	..	..	..	..	..	..	1
Miscellaneous	3	5	2	..	1	1	3	..	5	..	2	..	4	26
Morocco Leather (see also Tanneries)	5	3	..	..	2	..	1	..	..	..	..	..	1	12
Motion Picture Exchanges..	..	..	..	..	..	..	..	..	2	..	..	..	..	2
Motion Picture Theatres...	2	1	..	..	..	..	..	..	..	..	1	1	..	5
Multiple Occupancy	..	..	..	1	..	..	2	..	..	1	..	..	..	4
Munition Plants	2	..	..	1	..	..	..	..	4	1	..	..	1	9
Musical Instrum't Factories	1	4	..	..	..	..	1	..	..	..	1	..	..	7
Oil Cloth Works	..	..	..	..	..	..	..	1	6	..	..	..	..	7
Oil Clothing Factories	..	..	..	..	..	..	..	..	..	..	..	..	1	1
Oil Refineries—Vegetable...	2	..	2	..	..	..	..	..	..	..	..	..	..	4
Packing Houses	1	2	1	..	2	..	..	..	1	1	..	..	1	9
Paint and Varnish Works...	2	3	5	..	..	..	3	..	1	..	..	..	..	14
Paper Box & Paper Products	5	1	..	..	1	..	..	..	..	..	..	..	..	7
Paper Coating Mills	1	..	..	..	..	..	..	2	..	..	..	..	..	3
Paper Mills	24	23	13	3	1	3	2	3	4	3	2	1	13	95
Patent Leather (see also Tanneries)	1	..	1	1	..	..	1	..	..	..	1	..	..	5
Phonograph Works	1	..	..	..	..	..	..	..	..	..	..	..	..	1
Photograph Establishments.	1	..	..	..	..	..	..	..	..	..	..	..	..	1
Picture Frame Mfg	1	2	1	1	..	..	..	1	..	..	..	..	..	6
Piers and Wharves	..	1	1	..	..	..	..	..	..	..	..	..	..	2
Plumbers' Supplies	1	..	..	..	..	..	..	..	..	..	..	..	..	1
Potteries	2	1	1	1	..	..	..	..	..	1	..	..	..	6
Printing and Lithographing.	8	4	1	..	..	..	1	1	1	..	3	..	1	20
Pulp Mills	10	4	4	..	1	1	1	..	1	1	..	..	2	25
Pyroxylin Plastic Mfg. and Fabricating	3	1	3	1	1	..	2	2	11	5	2	..	..	31
Radio and Accessories	1	..	..	..	..	..	..	..	..	..	..	1	..	2
Railroad Property	..	..	..	..	..	..	..	..	..	..	..	1	..	1
Restaurants	1	1	..	..	..	..	1	..	..	..	..	..	..	3
Rice Mills	..	1	1	..	..	..	..	..	..	..	..	..	1	3
Rolling, Wire & Tube Mills	..	..	..	..	1	1	1	..	..	..	..	..	..	3
Roofing Works	3	2	..	1	..	..	1	1	..	1	..	..	..	9
Rooming Houses	1	..	..	..	..	..	..	..	..	..	..	..	..	1
Rubber Cloth Works	2	..	..	..	..	..	..	..	..	..	..	..	1	3
Rubber Mills	8	..	..	1	..	..	..	1	5	4	..	1	1	21
Rubber Reclaiming Works..	2	..	..	..	..	..	1	1	1	1	1	..	..	7
Saw and Planing Mills	14	12	4	..	5	1	6	2	5	..	5	1	4	59
Ships and Shipyards	1	..	..	..	..	..	..	..	..	..	..	..	..	1
Shoddy Mills	6	3	6	..	1	3	1	1	..	..	..	..	1	22
Shoe Factories	18	6	3	..	..	1	..	2	..	2	5	..	3	40

	Water shut off sprinklers.	Generally defective equipment and unsprinklered portions.	Defective water supply or supplies.	Sprinkler system crippled due to freezing.	Slow operation of dry system or defective dry valve.	Slow or defective operation of high test heads.	Faulty building construction, concealed spaces, vertical openings.	Obstruction to distribution.	Hazard of occupancy too severe for average sprinkler equipment.	Sprinkler system crippled by explosion.	Exposure or conflagration.	Plugged heads.	Miscellaneous.	Total.
Shoe Mfg. Accessories	1	2	..	..	..	..	..	..	..	..	..	..	1	4
Silk Mills	2	1	..	..	..	..	..	..	..	1	..	..	1	5
Skin Mills	..	..	..	..	1	..	..	..	..	..	..	..	..	1
Soap Manufacturing	2	1	..	..	..	..	..	..	..	..	..	..	..	3
Stamping & Sht. Metal Wks.	2	4	1	..	1	..	2	1	..	1	2	..	1	15
Starch and Glucose Works.	..	..	..	..	..	..	..	..	1	7	..	..	..	8
Sugar Refineries	1	1	..	..	..	..	..	..	..	1	..	..	..	3
Tanneries	1	1	..	3	..	..	..	..	1	..	1	..	1	8
Tenant Manufacturing	38	8	2	3	1	..	3	1	1	..	6	1	3	67
Theatres	4	3	..	..	..	..	..	..	..	..	..	..	..	7
Tobacco Factories	1	1	..	..	..	..	..	..	..	..	1	..	..	3
Trunk Factories	2	1	..	..	..	..	..	..	..	..	..	..	..	3
Umbrella Mfg.	..	..	..	..	..	..	..	..	1	..	..	..	..	1
Vacant Buildings	1	1	..	..	..	..	..	..	..	..	..	..	..	2
Wall Paper Factories	..	..	1	..	..	..	..	1	1	..	1	..	..	4
Warehouses	16	5	3	..	3	..	2	4	2	..	..	..	4	39
Waste and Batting Mills	7	4	4	2	..	1	..	2	2	..	..	..	1	23
Waste Paper and Rag Shops	4	1	..	..	..	..	..	..	..	..	..	..	1	6
Weaving Mills	1	2	2	1	..	..	..	1	..	..	..	..	..	7
Window Shade Factories	..	..	..	1	..	..	..	..	1	..	..	..	..	2
Woodworkers, Class A*	12	9	4	..	1	1	1	6	1	3	3	1	4	46
Woodworkers, Class B*	6	9	2	2	1	2	1	1	..	3	2	..	3	32
Woodworkers, Class C*	5	4	2	..	..	..	..	3	..	..	..	..	..	14
Woodworkers, Class D*	2	10	..	1	1	..	..	..	..	2	4	..	3	23
Woodworkers, Class E*	5	2	1	..	2	1	2	..	..	..	1	..	..	14
Woodworkers, Class F*	2	..	1	..	..	..	..	1	..	..	..	..	..	4
Woolen Mills	17	19	14	1	..	2	4	..	1	..	3	..	9	70
Wool Scouring Plants	..	1	1	..	..	..	1	..	..	..	..	..	..	3
Wool Storehouses	..	2	..	..	..	..	..	..	..	..	..	..	1	3
Worsted Mills	3	3	2	1	..	..	1	..	..	..	..	..	4	14
Total Unsatisfactory Fires	565	347	161	48	52	25	90	97	106	81	75	23	128	1798

*The Woodworkers are classed as follows:

Class A. Interior Woodwork, builders' supplies (including veneer works).

Class B. Box Factories (including cigar boxes).

Class C. Miscellaneous Woodworkers. Steam power tenant Woodworkers. Woodworkers where there is a lack of detailed information as to class.

Class D. Sash, Door and Blind Factories.

Class E. Hard Wood Turning (wheels, pipes, novelties, bobbins, spools, etc., last and wood heel factories).

Class F. Pails and Woodenware (plates, wooden bowls, tubs, etc.).

†Other Metal Working Occupancies are included under Agricultural Implements; Automobile and Bicycle Factories; Bolt, Nut and Screw Works; Electrical Appliances; Forge and Smithy; Foundries; Machine Works; Rolling, Wire and Tube Works; and Stamping and Sheet Metal Works.

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National Fire Protection Association

INTERNATIONAL

Executive Office: 60 Batterymarch St., Boston, Mass.

The National Fire Protection Association was organized in 1895 to promote the science and improve the methods of fire protection and prevention, to obtain and circulate information on these subjects and to secure the coöperation of its members in establishing proper safeguards against loss of life and property by fire. Its membership includes over a hundred national and regional societies and associations and more than four thousand individuals, corporations, and organizations.

The QUARTERLY is one of a large number of publications issued by the Association and sent to the members as published. These include the monthly *News Letter,* standard regulations on fire prevention and fire protection, special reports and bulletins, the Year Book, and the Proceedings of the annual meetings.

Membership in the National Fire Protection Association is open to any Society, Corporation, Firm or Individual interested in the protection of life or property against loss by fire. All the valuable engineering and popular literature issued by the Association is sent, as issued, to every member. The Association is the clearing house for all the authoritative information on Fire Protection and Prevention, and members are privileged to submit to it their individual problems for solution. The Association is always glad to send samples of its publications to prospective members upon request.